

SAFETY in the **SKIES**

Institute for Civil Justice • RAND

**Personnel and
Parties in NTSB
Aviation Accident
Investigations:
MASTER VOLUME**



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PREFACE

The daily movement of millions of passengers over distances thought impossible merely a century ago is emblematic of the modern transportation era—an era characterized by speed and personal convenience. The commerce of aviation, both the operation of commercial aircraft for profit and the development of aeronautical systems, is also an important symbol of national prestige and a powerful economic force. Safety in air transportation is, therefore, a matter of profound national importance.

The National Transportation Safety Board (NTSB) plays a central role in the overall equation of aviation safety. The agency enjoys the reputation of being the most important independent safety investigative authority in the world; the caliber of its investigations has become the international standard. The NTSB is considered to be the best in the business and has served as a model for independent investigative authorities in many countries. However, recent major commercial aviation accidents, such as TWA Flight 800 and USAir Flight 427, have stretched the resources of the NTSB to the limit and have challenged the ability of the technical staff to unravel the kinds of complex failures that led to such horrific tragedies.

Preserving and enhancing the NTSB's ability to fulfill its crucial safety mission were the central motivations for this research and are the guiding principles behind the recommendations that are proposed. Recognizing the strain now being placed upon the limited resources of the safety board and its technical staff, NTSB Chairman Jim Hall sought a self-critical examination of the agency's capability to carry out one of its most important and visible assignments: the investigation of major commercial aviation accidents. Chairman Hall requested that the inquiry substantially pertain to this subject, with application where appropriate to the other transportation modes under the NTSB's jurisdiction.

Although the NTSB investigates thousands of general aviation, marine, rail, highway, and other transportation accidents every year,

the public reputation and credibility of the safety board substantially rest on its ability to determine the cause of major commercial aviation accidents. It is also in this area that the NTSB's independence has been most vigorously challenged by the many stakeholders whose interests may be affected by the outcome of an investigation.

In undertaking this research, RAND was able to involve personnel with expertise in several disciplines from three RAND programs: the Institute for Civil Justice, the Science and Technology Policy Institute, and Project AIR FORCE. This multidisciplinary approach enabled the researchers to use a variety of quantitative and qualitative research techniques to examine the inner workings of the NTSB closely. This research provides the most comprehensive examination of NTSB operations that has ever been undertaken in the 30-year history of the agency.

We commend this report to serious consideration by the NTSB and all the affected interest groups and stakeholders involved with the investigation of major commercial aviation and other transportation accidents. The report offers significant insights into the existing investigative process and, at the same time, sets forth important recommendations aimed at strengthening the safety board's ability to carry out its essential safety mission. We believe the report makes a significant contribution to assuring the safety of the traveling public and to the advancement of public policymaking in this most important field.

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A central element of this study was obtaining access to NTSB data sources and information about the accidents selected for review. The authors wish to thank the staffs of the NTSB's Offices of the Chief Financial Officer, Human Resources, Government, Public and Family Affairs, Aviation Safety, Research and Engineering, and Safety Recommendations and Accomplishments for their cooperation, patience, and support. Personnel in all of these offices provided rapid response to our inquiries and were available to assist us in obtaining the information we requested. A special thanks also goes to Henry Hughes, a senior investigator at the NTSB, who went to extraordinary lengths to provide special insights into safety board operations. The authors would also like to thank C. O. Miller, who, although long retired from the NTSB, continues to offer valuable insights and institutional memory that proved to be of great assistance in our research.

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The aviation community is represented by many domestic and international organizations that RAND turned to for key elements of the research. Especially supportive of RAND's research were the Air Line Pilots Association, the Air Transport Association, the Flight Safety Foundation, and the National Air Traffic Controllers Association. RAND is also deeply grateful to the many individuals who have lost loved ones in aviation accidents who came forward to support this research and to provide personal insights of immense value. We would particularly like to acknowledge the encouragement provided by Hans Ephraimson-Apt, Jim Hurd, and the National Air Disaster Alliance, an organization that represents families of victims of major commercial air crashes.

Aviation accident investigation is an activity that involves many stakeholders in the aviation, aviation insurance, and legal communities. We would like to express our appreciation to the many individuals who took the time to meet with us and were willing to participate in lengthy confidential interviews regarding the NTSB investigative process and its influence on civil litigation. We benefited greatly from these interviews and our research was enriched by the candor with which many interviewees approached this task. We appreciate their professional courtesy and insightful discussions, which we hope were of mutual benefit.

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ABBREVIATIONS

AADB	Aviation Accident Database [NTSB]
AAIB	Aviation Accident Investigation Board [Great Britain]
ABA	American Bar Association
ADREP	Accident Data Reporting System [ICAO]
ADS-B	Automatic Dependent Surveillance System with Broadcast Capability
AFB	Air Force Base
AFSC	Air Force Safety Center
AIDS	Accident/Incident Data System [FAA]
AILS	Airborne Information for Lateral Spacing
ALPA	Air Line Pilots Association
AML	Approved Materials List
AOAS	Advanced Oceanic Automation System
AOPA	Aircraft Owners and Pilots Association
APMS	Aviation Performance Measuring System [NASA]
ARAC	Aviation Rulemaking Advisory Committee
ASI	Air Safety Investigator
ASIP	Aircraft Structural Integrity Program
ASRS	Aviation Safety Reporting System
ATC	Air traffic control
ATR	Avions de Transport Regional [European Aerospatiale]
BASI	Bureau of Air Safety Investigation [Australia]
BEA	Bureau Enquetes-Accidents [France]
CAA	Civil Aeronautics Administration
CAB	Civil Aeronautics Board
CAE	Computer-aided engineering
CAIR	Confidential Aviation Incident Report [Australia]
CAMI	Civil Aeromedical Institute [FAA]
CARMA	Computer-aided reliability/maintainability analysis
CATIA	Computer-aided three-dimensional interactive approach
CBT	Computer-based training
CFIT	Controlled flight into terrain

CFO	Chief financial officer
CFR	Code of Federal Regulations
CHIRP	Confidential Human Factors Incident Report Program [Great Britain]
CNS	Communications, Navigation, and Surveillance
COS	Community of Science
CST	Central Standard Time
CVR	Cockpit voice recorder
CWT	Center wing fuel tank
DA	Descent Advisor
DOD	Department of Defense
DOT	Department of Transportation
DROM	Dynamic runway occupancy measurement
DSO	Design service objective
EAA	Experimental Aircraft Association
EDT	Eastern Daylight Time
EGPWS	Enhanced ground proximity warning system
EPA	U.S. Environmental Protection Agency
EST	Eastern Standard Time
EUCARE	The European Union's Confidential Aviation Safety Reporting Network
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FBI	Federal Bureau of Investigation
FDR	Flight data recorder
FinAst	Financial accounting system [NTSB]
FOQA	Flight Operational Quality Assurance
FRA	Federal Railroad Administration
FRE	Federal Rules of Evidence
FTE	Full-time equivalent
FY	Fiscal year
GA	General aviation
GAIN	Global Aviation Information Network
GAMA	General Aviation Manufacturers Association
GAO	General Accounting Office

GPS	Global Positioning Satellite
GPWS	Ground proximity warning system
GS	Government Service
Hi-Rel	High Reliability
ICAO	International Civil Aviation Organization
ICARUS--	Information Collected Anonymously and Reported Universally
CARS	for Safety--Confidential Aviation Reporting System [New Zealand]
ICJ	Institute for Civil Justice
IDACS	Intelligent Damage Adaptive Control System
IFR	Instrument flight rules
IIC	Investigator-in-charge
IPPS	Integrated Personnel Payroll System [DOT]
IPT	Integrated Product Team
IRAN	Inspect and Repair As Necessary
ISBA	Independent Safety Board Act of 1974
KM	Knowledge management
LEO	Low earth orbit
LIDAR	Laser Instrument Distance and Range Detection
LMC	Lockheed Martin Corporation
MB	Megabyte
MCM	Multichip module
MEM	Micro electromechanical systems
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASDAC	National Aviation Safety Data Analysis Center [FAA]
NCAC	National Crash Analysis Center
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NTSB	National Transportation Safety Board
NTTC	National Technology Transfer Center
OAS	Office of Aviation Safety
OJT	On-the-job training
OPM	Office of Personnel Management
ORE	Office of Research and Engineering

OSRA	Office of Safety Recommendations and Accomplishments [NTSB]
P-FAST	Passive Final Approach Spacing Tool
PA	Product assurance
PCU	Power control unit
PDM	Programmed depot maintenance
PEM	Plastic encapsulated microcircuit
PM	Project manager
RaDiUS	Research and Development in the United States
RLV	Reusable launch vehicle
ROTO	Roll out and turn off
SAASCO	Southern African Aviation Safety Council [South Africa]
SIRS	Safety Issues Reporting System [Canada]
SMA	Surface movement advisor
SRIS	Safety Recommendations Information System
STC	Space transition corridor
SUA	Special use area
T/ADWR	Terminal Advanced Doppler Weather Radar
TCAS	Traffic Alert and Collision Avoidance System
T-NASA	Taxi Navigation and Situational Awareness
TMA	Traffic Management Advisor
TSB	Transportation Safety Board [Canada]
TWA	Trans World Airlines
UAV	Unmanned aerial vehicle
USC	United States Code
VFR	Visual flight rules
VLTA	Very large transport airplanes
VRC	Virtual Research Center [NASA]
WFD	Widespread fatigue damage
WHCASS	The White House Commission on Aviation Safety and Security

SUMMARY

The National Transportation Safety Board bears a significant share of the responsibility for ensuring the safety of domestic and international air travel. Although it is not a regulatory agency, the NTSB's influence weighs heavily when matters of transportation safety are at issue. The NTSB is independent from every other Executive Branch department or agency, and its mission is simple and straightforward: to investigate and establish the facts, circumstances, and the probable cause of various kinds of major transportation accidents.

The Safety Board is also charged with making safety recommendations to federal, state, and local agencies to prevent similar accidents from happening in the future.¹ This responsibility is fundamental to ensuring that unsafe conditions are identified and that appropriate corrective action is taken as soon as possible. The Safety Board has no enforcement authority other than the persuasive power of its investigations and the immediacy of its recommendations. In the scheme of government, the NTSB's clout is unique and contingent upon the independence, timeliness, and accuracy of its factual findings and analytical conclusions.

As commercial air travel has become routine for millions of passengers, increasingly, the NTSB has no choice but to conduct its investigations of major accidents under the glare of intense media attention and public scrutiny. At the same time, an NTSB statement of cause can have severe consequences for an airline, aircraft manufacturer, or other entity that may be deemed responsible for a mishap. A very real, albeit unintended, consequence of the NTSB's safety investigation is the assignment of fault or blame for the accident by both the courts and the media. Hundreds of millions of dollars in liability payments, and the international reputation of some of America's most influential corporations, rest on the NTSB's conclusions

¹The term "Safety Board" is used throughout as a short form for the NTSB. RAND uses the term "Board members" to refer to the five politically appointed members of the Board of the NTSB.

about the cause of a major accident. This was not the system that was intended by those who supported the creation of an independent investigative authority more than 30 years ago, but it is the environment within which the investigative work of the agency is performed today.

The NTSB relies on teamwork to resolve accidents, naming "parties" that include manufacturers, operators, and, by law, the Federal Aviation Administration (FAA) to participate in the investigation. This collaborative arrangement works well under most circumstances, leveraging NTSB resources and providing critical information relevant to the safety-related purpose of the NTSB investigation. However, the reliability of the party process has always had the potential to be compromised by the fact that the parties most likely to be named to assist in the investigation are also likely to be named defendants in related civil litigation. This inherent conflict of interest may jeopardize, or be perceived to jeopardize, the integrity of the NTSB investigation. Concern about the party process has heightened as the potential losses resulting from a major crash, in terms of liability and corporate reputation, have escalated and the importance of NTSB findings to the litigation of air crash cases has grown.

The NTSB's ability to lead investigations and to form expert teams is threatened by a lack of training, equipment, and facilities and by poor control of information. Additionally, the need to modernize certain investigative practices and procedures is particularly acute. In some respects, the NTSB's investigative techniques have not kept pace with changes in modern aircraft design, manufacturing, and operation, raising doubts about its ability to expeditiously and conclusively resolve complex accidents.

Clearly the NTSB needs additional resources, but management reform is no less vital. Ensuring effective use of resources first requires adequate means of monitoring expenditures. A lack of even rudimentary project-type financial accounting prevents the NTSB from monitoring such important parameters as staff workload. In this report, RAND outlines a set of recommendations aimed at helping to ensure that the NTSB can meet the demands of the future. While the tenets upon which the NTSB was

originally created remain sound, new approaches outlined in the recommendations are necessary to meet the demands of a more complex aviation system.

The sections that follow summarize the study objectives, the approach RAND used, the study findings, and the overall conclusions and recommendations.

OBJECTIVES AND SCOPE OF THE STUDY

This research had two original objectives that go to the heart of the NTSB investigative process:

- Examine NTSB practices and policies with regard to the training and qualifications of aviation accident investigators, and assess the adequacy of such policies and practices in light of the emerging aviation environment.
- Review the functioning of the party process as a means of supplementing the skills and technical knowledge of the NTSB staff and examine the current liability environment in which the party system operates.

RAND worked with NTSB senior managers to specifically augment the scope of the research in selected areas. For example, whereas original study objectives called for an examination of NTSB training policies, it quickly became apparent that maintaining a capable staff depends not just on training but also on hiring policies and staff workloads. The scope of the research work was subsequently expanded to address hiring and workload issues.

The breadth of the research should also be noted. The extent to which the research objectives could be explored was limited by funding. Resource limitations demanded that RAND focus its analysis on aviation accidents, while largely ignoring the other areas of NTSB authority. Some aspects of the research could only be touched upon, leaving others inside or outside the NTSB to expand upon the themes identified by RAND. In such cases, RAND characterized the issues for the NTSB and recommended additional research and analysis with more focused objectives.

RESEARCH APPROACH

A multidisciplinary research team developed a five-phase research plan to identify critical issues and illuminate the various challenges facing the NTSB. The phases included (1) development of an operational baseline; (2) characterization of the emerging aviation environment; (3) review of the liability environment; (4) review of staffing, workload, and training; and (5) review of internal NTSB processes. This analysis provided a historical perspective of the NTSB, a detailed study of its current procedures and capabilities, and an examination of aviation trends to assess the challenges these trends will pose to NTSB operations in the future.

RAND used internal NTSB records on personnel, workload, training, budgets, accidents, and accident reports to assess NTSB operations. To augment the NTSB's quantitative data, RAND utilized a structured questionnaire, a set of structured interviews with NTSB staff and members of the aviation community, a legal review, site visits, and a series of three workshops. Additionally, RAND relied on extensive telephone interviews, an exhaustive literature review, and extensive use of Internet-based quantitative and qualitative data to supplement the other research methods. Collectively, the numerous data sources provided a rich set of information with which to develop case studies and perform other more quantitative data analyses that addressed project objectives.

STUDY FINDINGS

The NTSB is widely acknowledged as the leading transportation accident investigation agency in the world. However, under the demands of increasing complexity in aircraft design and the ever-greater stakes surrounding accident investigations, the NTSB is nearing the breaking point. Although it continues to operate effectively to support the Safety Board's mission in the majority of cases, the party process can become a limited resource the more there is at stake.

The need for solid NTSB leadership has never been greater. However, the methods used to train and equip the NTSB staff are insufficient and must be enhanced to ensure continued independence of the Safety Board. Improved investigative methods are also needed and

better ways must be found to control information and manage NTSB resources. The following section summarizes RAND's major findings, and the final section summarizes conclusions and recommendations that form the steps to be taken to improve and revitalize the NTSB.

Lack of Resources Is Bringing the NTSB Close to the Breaking Point

The NTSB is one of the smallest federal agencies. With a fiscal year 1999 budget of \$56 million and a staff of 400 employees, the agency must cover five major fields of accident investigation. Of the approximately 270 professional staff members at the NTSB, half are dedicated to the investigation of aviation accidents. In aviation, the NTSB focus is on air transport accidents. Over the past 20 years, the worldwide commercial air transport fleet has more than doubled to more than 12,000 aircraft of both U.S. and foreign manufacture.

The NTSB also has responsibility for investigating accidents in the general aviation (GA) community: corporate aircraft, rotorcraft, and other small private and experimental aircraft, constituting a fleet of approximately 180,000 vehicles. Annually, the NTSB investigates more than 2,000 large and small aircraft accidents and incidents, more than 15 events for each NTSB aviation professional.

The NTSB's budget and staffing have grown in an attempt to keep pace with increasing demands.² *Despite this growth of resources, the NTSB is facing a serious work overload resulting from demand for its services and is in urgent need of additional resources and management reform.* Such a dramatic finding may seem contrary to the high esteem in which the NTSB is usually held. The NTSB enjoys a reputation for technical excellence and unquestioned independence throughout the world. Indeed, its practices have spawned similar organizations in many other countries, and its investigators and technical support staff are called upon increasingly to support foreign accident investigations. But beneath the surface, the NTSB is running to stay in place. One measure of this struggle is reflected in the employee workload.

²In constant dollars, both the NTSB's budget and staffing have risen by 35 percent since 1980.

The sustained average workweek for NTSB aviation professionals is 50 hours--consistently longer than the average workweek for employees in comparable professional occupations in the United States as a whole. During a major accident investigation, the average workweek can climb to 60 hours; peak workload hours can go even higher still. Compounding the demands from long working hours is the nature of air crash investigative work. In this high-stress profession, NTSB staff are exposed to gruesome crash scenes, media frenzy, the emotional trauma of dealing with victims' families, and the pressure to conduct technically unassailable analyses that identify the probable cause of accidents. When time pressure is added to the equation, the result is a professional staff on the edge of burnout.

RAND found a highly dedicated and motivated staff, and this professionalism has allowed the Safety Board to maintain its traditional superior standard of performance. Over the long term, however, RAND believes that the NTSB's ability to sustain both excellence and independence cannot be ensured. These findings are consistent with other studies that have expressed concern about workload and stress at the NTSB.³

RAND found that the time required to complete a major accident report and the accident rate are closely coupled. Another measure of work overload can be found in the growing delays in completing investigations. The average time to complete a Final Accident Report is rising; for major accidents, the time period is increasing at an alarming rate. The NTSB's investigation of the USAir Flight 427 crash in 1994 took more than four years to complete.

Tardiness in completing an accident investigation is antithetical to the goal of improving air safety. Although the NTSB does provide recommendations for safety improvements early in an investigation and throughout the process, the fact remains that unsafe conditions could exist for years until the completion of the NTSB's technical analysis. Victims' families must also endure a long period of uncertainty and

³For example, see Coarsey-Rader, January 22, 1998.

delays in related civil legal proceedings pending completion of the NTSB investigation.

Some observers might ask how the NTSB could be approaching overload in an era when domestic airline crashes appear to be (and are supposed to be) increasingly rare occurrences. The answer has both simple and complex components. The most important element for understanding the issues facing the NTSB is *growth*. The NTSB is experiencing growth across the board--in aircraft complexity, in the magnitude of the investigations, and in the number of investigations it is called upon to conduct.

It is important to recognize that the NTSB's investigative portfolio goes well beyond major domestic airline accidents. The Safety Board must investigate accidents and major incidents in all sectors of aviation. Furthermore, the NTSB investigates both fatal *and* nonfatal accidents. When the history of accidents is reviewed, the rising workload picture becomes clearer. The fatal accident rate has been stubbornly consistent over time, with approximately one fatal commercial transport accident occurring every two months. The nonfatal accident rate has nearly doubled over the past five years. These statistics are major indicators of the NTSB's work levels. The principal recipients of this increasing workload are the Major Investigations Division staff within the Office of Aviation Safety, whose work log shows a 30 percent increase in the number of accidents and major incidents the staff has been called upon to support over the past 10 years.

The relatively steady number of fatal accidents combined with recent growth in the number of nonfatal accidents only partly explain the NTSB's increasing workload, given that the agency has dealt with increased accident rates in the past. An additional factor is the increasing complexity of air crashes. Complexity comes in many forms. Fundamentally, aircraft are very complex devices; when they crash, the amount of analysis required to establish causal factors is commensurately complex.

When a complex system fails, the number of potential scenarios rises in proportion to the complexity of the system. NTSB investigators must carefully unravel the performance of many highly integrated

systems, a very time-consuming task requiring a diverse set of skills. Often, this requires extensive and costly salvage and reconstruction of the aircraft. Complexity affects more than just staff workload. The growing complexity of aircraft crashes also has a profound effect on how investigations must be structured to reveal hidden failure modes.

The size and capacity of an aircraft has a significant bearing on the complexity of an accident investigation. Commercial aircraft of the future will have a comparatively greater capacity than the fleet of today; a single airplane, such as the Boeing 747-400, is capable of carrying more than 500 passengers. The crash of a single plane in which hundreds of people are killed, would virtually consume the NTSB staff, and few resources would remain available for other investigations. Aging aircraft issues could also become more important in aviation accident investigations as the fleet ages, although there is insufficient evidence to predict an increased accident rate based on aircraft age alone.

The NTSB is also called upon increasingly to support international investigations. In many cases, the NTSB is not required to dispatch resources abroad to support these requests; nevertheless, support to on-site investigations is increasing. The magnitude of international work is reflected in the number of dispatches made by the staff of the Major Investigations Division of the Office of Aviation Safety (OAS). In 1998, senior investigators were dispatched to more than twice as many foreign accidents as domestic accidents. Clearly, international efforts are a significant contributor to NTSB workload.

Finally, a major factor in the NTSB's workload is the amount of resources devoted to GA, or Part 91, investigations. The NTSB investigates many hundreds of GA accidents per year through its regional and field offices. Nearly half of the resources of the OAS (mostly in the field and regional offices) are devoted to the investigation of GA accidents. There is no way to assess future GA accident trends definitively, although various factors indicate that it is unlikely that the rate will decline significantly.

Previous declines in GA accidents were principally due to reductions in the amount of flying. However, this sector is growing in

popularity, a trend that could portend a significant rise in the accident rate. However, accident numbers and the size of the fleet do not tell the full story of GA accident investigation. The NTSB faces a renaissance in GA, reflected in the extraordinary diversity in the types of aircraft now being flown. An accident investigator dispatched to a GA crash site could find a traditional metal airplane of known heritage, a homebuilt aircraft, or a vintage fighter aircraft of foreign manufacture. The crash of a GA aircraft can also result in a complex investigation. Many GA aircraft, especially new homebuilt designs and kit aircraft, are assembled and operated using state-of-the-art technology. In addition, some GA aircraft accidents have involved famous individuals, which resulted in a great deal of public and media attention.

A small percentage of GA accidents lead to the identification of safety issues and the issuance of industrywide safety recommendations; with many others, the cause of the accident is unremarkable. Given that large workloads can affect the quality and timeliness of investigations, the process used to respond to GA accidents is a matter of great importance.

Avoiding a breakdown at the NTSB will require the cautious infusion of additional resources, redesign of internal NTSB practices, and exemplary leadership. These measures are necessary to ensure the continued vitality and independence of the Safety Board. Taking these steps is a matter of considerable national importance in the face of new and ambitious air safety and security goals.

Limitations in the Party Process Must Be Addressed

The stated mission of the NTSB is to investigate the facts, circumstances, and probable cause of an accident and to make recommendations for preventing similar accidents from happening in the future. Typically, this activity takes place within an environment permeated by the aviation liability and claiming process. The effects of litigation begin to be felt immediately after an accident occurs. The specter of lawsuits arises as soon as the magnitude of the tragedy is known. The parties likely to be named to assist in an NTSB

investigation--such as the air carrier and aircraft or component manufacturers--are also the parties most likely to be named defendants in the civil litigation that inevitably follows a major accident. The investigation process, inherently important to the safety of the flying public, has become equally, albeit unintentionally, important to the ultimate establishment of legal fault and blame.

The effective separation of the NTSB investigative process from the litigation process is an ideal that has little connection to the reality of current practice. Isolation of the NTSB from the litigation environment is virtually impossible as long as the NTSB relies substantially on the party process in a major investigation and, conversely, as long as the litigation and resolution of claims substantially depend on NTSB findings. Few limits remain on the use of NTSB reports in civil litigation. As a consequence, NTSB final accident reports, which both plaintiff and defense attorneys often consider the "road maps to liability," figure prominently in court proceedings.

The stakes surrounding aviation accident litigation have evolved just as the industry itself has evolved. Today's jumbo jets routinely transport hundreds of passengers. Commercial air crash litigation exposes the principal defendants--most often the airline or aircraft manufacturers--to the risk of assuming liability for dozens, even hundreds, of deaths or injuries. Beyond the multimillion dollar awards, such litigation is highly publicized, subjecting the defendants to extensive adverse publicity that may affect market share and international competitiveness.

Although RAND's benchmark 1988 study of the compensation of aviation victims has not been updated (Kakalik et al., 1988), confidential interviews with numerous insurers and plaintiff and defense lawyers reveal a more litigious climate in recent years, characterized by fewer early settlements, the increased involvement of aviation specialists, and a propensity for family groups and individual claimants to pursue litigation as an alternative means of determining what happened to cause an accident.

The party process presents inherent conflicts of interest for entities that are both parties in an investigation and "parties

defendant" in related litigation. Indeed, RAND has found that, at least in certain types of complex accidents, the party system is potentially unreliable and party representatives may be acting to further various interests beyond just the prevention of a similar sort of accident. Such potential conflicts may, in some instances, threaten the integrity of the NTSB investigative process, raising numerous questions about the extent to which party representatives are motivated to influence the outcome of the safety-related investigation in anticipation of litigation.

NTSB rules governing party participation were designed to be sufficiently stringent to ensure that the parties do not prejudice the investigation. Regulations specifically bar lawyers for the parties from participating in an investigation. However, anecdotal information indicates that some lawyers remain in proximity to the investigative process as advisors to party representatives. Furthermore, insurers are routinely granted access to the crash site that may not be open to any other party or claimant.

NTSB rules also bar family members, claimants, and their representatives from participating in an investigation. From the perspective of family members whose loved ones have perished in an aviation disaster, no issue is more frustrating than exclusion from the party process, particularly because the essential purpose of an NTSB investigation is to determine "what happened" and to prevent it from happening again. Family members contend that they have an equal, if not greater, interest in accident prevention than any party to an investigation. Plaintiffs and their attorneys complain that permitting an airline, aircraft manufacturer, or other defendants to participate in the NTSB investigation puts the victims at a serious disadvantage from the beginning of a case, a disadvantage that may continue for months or years until the NTSB investigation is concluded.

Despite the emotional appeal of this suggested reform to the NTSB rules, there are a number of well-grounded objections to family member participation in the NTSB party process. Foremost among these concerns is the difficulty of selecting an appropriate "family representative" from among numerous family members and their attorneys without

exacerbating concerns about client solicitation or violating the NTSB requirement that party representatives possess specific technical expertise. At the same time, expanding the role of party representatives to allow party participation, beyond written submissions, in the NTSB analytical and report-writing process would only amplify concerns over potential or perceived conflicts of interest inherent in the party process.

Despite its limitations, the party system is a key component of the NTSB investigative process. Parties are uniquely able to provide essential information that simply cannot be obtained elsewhere about aircraft design and manufacture, airline operations, and functioning of flight systems. However, in accidents that implicate fleet design or operations, or that involve costly product liability, design defect claims, or the failure of complex systems, there may be limits to the effectiveness or integrity of the party system. These kinds of accidents also tend to involve significant threats to the competitive position of one or more of the parties and have resulted in NTSB investigations that last two years or more.

Selectively increasing NTSB resources and expertise will help ensure that the agency can provide unquestioned leadership in complex investigations. Augmenting the party process through expanded use of nonparty resources or expertise provides an additional means of ensuring continued independent investigations, without threatening the traditional role of party representatives.

Lack of Training, Equipment, and Facilities Is Threatening NTSB Independence

The viability of the party process is inextricably linked to the NTSB's ability to lead complex investigations. All parties interested in national aviation safety agree that a well-trained and well-equipped Safety Board is essential to the agency's success. NTSB investigators must be able to ask the right questions and determine whether they have received the right answers.

Two driving forces determine how best to equip the NTSB and train its staff. The first is the nature of accident investigations, which includes an understanding of why the Safety Board is unlike most other

technical organizations. The second relates to how external events require a dynamic and evolutionary approach to hiring and training, and equipping the organization to meet pending challenges.

The job of investigating accidents is a difficult one. Accident investigators must demonstrate a broad set of technical skills and combine them with an acquired set of skills unique to an examination of technical failures on a massive scale. Also unique to the job is the challenge of maintaining technical proficiency. Pilots and engineers devote large amounts of their working lives to obtaining technical skills, and then refining and expanding their skill base through a combination of on-the-job training and additional professional development. This is not the case at the NTSB. A pilot, for example, may have 5,000 commercial flight hours in a transport category aircraft when joining the NTSB. Once he or she is inside the Safety Board, however, the piloting skills are no longer reinforced or developed. Without an aggressive, carefully implemented training plan, technical skills are likely to wither, and the employee becomes distanced from the accelerating state of the art.

Externally, the world of general and commercial aviation is undergoing dramatic changes that will shape the professional staff the NTSB requires and the way in which the agency maintains its facilities. For example, the fleet of aircraft, both private and commercial, that the NTSB must monitor is changing significantly. The number of transport aircraft needed to meet burgeoning demand will likely double by 2015. Most important, the makeup of that fleet is changing. New aircraft designs will not be a major component of fleet expansion; however, serial upgrades to existing designs will involve substantial changes at the system and subsystem levels. The NTSB must monitor and respond to this evolution.

The NTSB must also keep pace with the growing diversity of the fleet and developments in the manufacturing base. The percentage of foreign-built aircraft is expected to nearly double in the next 20 years, from 21 to 39 percent. The NTSB will have to become much more familiar with the design and operation of foreign-built aircraft than it is today, which will require working with foreign manufacturers,

operators, regulators, and accident investigators. This is particularly applicable to the regional or commuter aviation segment of the industry, in which the vast majority of the U.S. fleet is of foreign manufacture.

Change is not restricted to just the aircraft fleet. Fundamental changes are also occurring in the air traffic control system, the acquisition and transmission of flight performance data, and navigation methods. The magnitude of these developments is sweeping, and the NTSB has no formal or informal process for keeping pace with them. These changes will strongly influence the accident investigation process. In the near future, a flight's navigation record, for example, will derive from the satellite-based Global Positioning System (GPS) instead of the traditional radar record.

A variety of new vehicle types are expected to become operational during the next decade. These "aircraft" will include unmanned aerial vehicles, civil tilt-rotors, and possibly commercial reusable space launch vehicles. Because these vehicles will share the civil airspace with other aircraft, the NTSB will need to follow their evolution and become familiar with their design and operation.

The success of the NTSB depends on the continuing technical excellence of its staff, but at present it does not have a well-structured training program or a commensurate set of facilities that support both training and engineering analysis. Current levels of training are quite limited because of workload, funding, and other constraints, particularly when measured against the amount of training other members of the aviation community receive. Much of the training that does take place has an in-house orientation given that the NTSB relies on outside training opportunities to only a limited degree. Consequently, the NTSB's limited training program is not a reliable outlet for informing the professional staff about state-of-the-art technologies or the future aviation environment.

Because of the stochastic nature of accident events, investigators are often introduced to the intricacies of new equipment only when an accident occurs. There is no guarantee that investigating an accident involving an older aircraft, such as a Boeing 747-100, will prepare an investigator for a subsequent investigation involving a more modern

airliner, such as an Airbus 340 or a Boeing 777. The amount of available time for maintaining proficiency and acquiring new skills is very limited. For example, aviation investigators reported that they typically spend more than twice as much time answering public inquiries (such as accident scenarios posted on the Internet or mailed directly to the NTSB) as they do in training. This may reflect an inappropriate allocation of staff resources to this kind of noninvestigative activity.

The NTSB often hires experienced personnel who enter the agency at a high skill level. Over time, however, as workloads limit the frequency and extent of training, skill levels can diminish, forcing the NTSB to rely more heavily on the party process to supply the expertise needed to complete accident investigations. The result can be a steady erosion of staff skills. The current situation is particularly alarming because of the expectation that the NTSB will face more complex accident investigations in the future, especially those involving design-related issues associated with high levels of system integration.

Accident investigators must be trained not only in basic investigative techniques but also in a broad multidisciplinary routine matching the complexity of the systems they will be called upon to analyze. New approaches will be needed, and the NTSB must seek cooperative relationships with manufacturers, operators, academia, and other government agencies.

The integrity and independence of the Safety Board could be threatened if substantive changes in training programs do not occur. A more responsive training cycle would address many of the shortcomings of the current situation. To retain proficiency, investigators would train more frequently and to a greater extent, renewing their skills on a regular basis. In this circumstance, reliance on parties and outside expertise would be stabilized, thereby safeguarding the integrity of the accident investigation process.

Staffing is also of great importance. An inadequate training program only adds to staffing deficiencies, but acquiring new staff could pose a significant challenge. The Safety Board needs additional midcareer engineering professionals, but this market is highly competitive. Currently, the NTSB pays its midcareer engineering

professionals lower salaries than the rest of the aerospace industry. Although current attrition rates are relatively modest, salary levels could make it more difficult for the NTSB to attract and retain the skilled staff needed to perform the agency's future investigative work.

The NTSB's OAS also has a disproportionate number of older employees, including numerous staff at or above age 55. In a small organization having limited staffing depth, managing the replacement of older employees could pose a substantial challenge for the NTSB in the near future.

Finally, the NTSB's limited technical facilities lead to excessive dependence on party members for engineering analysis. These facilities cannot be used to any significant degree for training because they are fully committed for investigative work. The NTSB's approximately 4,000 square feet of laboratory facilities are barely adequate for the current workload. Resolving accidents of growing complexity will require many more investigative tools. The NTSB has not performed a strategic assessment of its current and future facility requirements, assessed opportunities for leveraging the capabilities of other federal agencies, or examined the investigative requirements of highly complex accidents.

Poor Control of Information Hampers Investigations

A major aircraft accident investigation generates tremendous amounts of information and data. Over time, the NTSB's institutional collection of air accident data has become a national resource. Accurate and timely information is essential to not just accurate and timely investigations, but also the identification of potentially dangerous trends and the ability to help the aviation community at large chart a course of continuing improvement in air safety.

The quality of the official record of domestic aviation accidents, known as the Aviation Accident Data Base, and other sets of data that the agency maintains, should be viewed as centrally important to the NTSB's overall mission. The accident record not only supports ongoing internal investigations but also is heavily used by external organizations, such as insurers and manufacturers, for planning and decisionmaking related to aviation safety. However, there is neither

oversight nor an emphasis on accuracy in the collection and maintenance of NTSB records. As a result, the accuracy of most of the NTSB data sources was rated as "poor" in the RAND analysis. Various offices control and manage information, with little coordination among them. This complicates the job of conducting investigations and diminishes outside users' confidence in the accident data.

The communication of information to and from the NTSB is another area needing improvement. As mentioned earlier, augmenting the party process will require that the NTSB monitor and acquire outside sources of information. However, the NTSB is an insulated organization--a proud, self-contained agency with limited ties to the broader aviation community. Change will be resisted. The NTSB's insularity is a by-product of its desire to preserve its independence and remain neutral during the course of aviation investigations. In an environment of growing complexity, this insularity seems to be unwise. The party process itself is based on the recognition that the NTSB cannot operate successfully on its own.

Through a network of new alliances with other government agencies and academia, enabled through a new emphasis on the acquisition and management of knowledge and expertise, the NTSB could efficiently augment its capabilities. The implementation of a "knowledge management" program that would afford ready identification of, and access to, outside resources would greatly assist in making expertise available at the time it is needed.

A less insular environment should also serve to expand training opportunities and encourage the NTSB technical staff to inform the aviation community about the wealth of knowledge acquired at great cost during the course of an investigation. The NTSB has important information to share and NTSB staff members acquire experience in many areas critically important to the goals of aviation safety--for example, in the area of aging aircraft. The NTSB has a responsibility to ensure that the knowledge and insights its technical staff acquires are shared as widely as possible with the aviation community.

Investigative Methods Need to Be Modernized

The nature of investigations and the future workload of the NTSB will be heavily influenced by the changing aviation environment, which is characterized by increasing technological complexity, growth in general and commercial aviation air traffic, and important changes in the composition of the air transport fleet. These factors have long challenged aviation accident investigators. Now, the pace of innovation is accelerating rapidly, and some of the developments ahead will put unprecedented strain on the NTSB. Most important, the adequacy of the investigative methods the NTSB has traditionally used will be challenged. These practices have remained largely unchanged since the inception of the NTSB in 1967.

The recent TWA Flight 800 and USAir Flight 427 accidents were not anomalies in terms of the complexity of the investigations that followed; rather, they are harbingers of the future. The growth in complexity is exponential in many areas, with the most significant trend being the interconnectedness of systems. Current-generation aircraft are highly integrated systems with extensive cross-linking. As complexity grows, hidden design or equipment defects become problems of increasing concern. More and more, aircraft functions rely on software, and electronic systems are replacing many mechanical components. Accidents involving complex events multiply the number of potential failure scenarios and present investigators with new failure modes. The NTSB must be prepared to meet the challenges that the rapid growth in systems complexity poses by developing new investigative practices.

Safety Board investigators are well prepared for accidents in which the failure mode reveals itself through careful examination of the wreckage and analysis of the debris--that is, those accidents in which a "permanent state failure" has occurred. Complex-system events, however, present greater challenges to traditional NTSB investigative practices. Here, failure states can be "reactive," *leaving no permanent record to discover in the wreckage*. In such cases, Safety Board investigative practices and analytical facilities and methods are less reliable.

The kinds of complex investigations the NTSB will face in the future will have attributes similar to those of applied research

projects. Solving complex accidents--those involving aircraft conceived and built in a structured team environment--will require the Safety Board to step beyond its current discipline-oriented "go-team" model. This model divides the accident investigation process into specific disciplines and assigns investigative teams to each of them. But this discipline-oriented focus does not reflect how modern complex aircraft are built and operated. The construction of aircraft relies on highly integrated, multidisciplinary teams.

The NTSB's traditional structure of discipline teams, coordinated through a single investigator-in-charge (IIC), does not encourage multidisciplinary analysis, testing, or synthesis. Such a structure is less likely to resolve problems of growing complexity. A network of multidisciplinary teams functioning in parallel and coordinated by a project manager (PM), might prove more conducive to the analysis of complex events.

Resolving the cause of a complex accident also depends on a thorough knowledge of prior incidents. While it has a *proactive* mission to prevent accidents, the NTSB tends to operate in a *reactive* manner. Incidents are usually investigated *after* accidents occur to identify parallels between the two. Investigation of incidents--episodes that may reveal systemic weaknesses or operational deficiencies, long before lives are lost--occurs comparatively rarely.

The number of major airline incidents the FAA reported in 1997 was 10 times the number of major accidents reported. Although the NTSB does examine many major incidents, only a small portion of the NTSB's aviation resources are focused on incident events. NTSB investigators rarely access outside data sources that describe incidents, and when a fatal accident occurs, the NTSB staff is frequently unaware of previous significant events. Although the NTSB's principal job is to examine accidents, the historically limited treatment of incidents means that investigators are not up to speed when an accident occurs.

The end product of the NTSB's investigation is the Final Accident Report. RAND also closely examined the process of developing Final Reports and preparing recommendations. Here, too, the Safety Board could streamline its process and improve the quality of its output. The

process of completing Final Reports puts heavy demands on NTSB professionals at all levels. The intensity of the report preparation workload will continue to be heavy, particularly for major accident investigations.

A review of the overall report preparation process would be an important first step. Among other things, the NTSB Board members should be afforded greater opportunity to monitor the progress of a report. In addition, Board members should have the authority, on a selected basis, to request peer review of the draft Final Report when the stakes are high and the investigation is lengthy and complex. The preparation of recommendations could also be more consistent and structured around a statement of expected performance rather than operational or design solutions.

The most controversial result of the NTSB's investigation process is the statement of probable cause found in the Final Report. The NTSB's fundamental objective is to investigate and establish the facts, circumstances, and cause or probable cause of accidents. Within the NTSB environment, the probable cause statement reflects the cumulative fact-finding and analysis of the NTSB investigative process. A statement of probable cause reverberates far beyond the halls of the NTSB. In terms of the assignment of fault and blame for a major aviation accident, by the media or in a legal proceeding, the NTSB's probable cause finding is a crucial one.

Probable cause sets off a chain reaction of regulatory activity that may result in the FAA issuing new safety regulations, airworthiness directives, service bulletins, or myriad other requirements. Beyond the regulatory effects, a finding of probable cause is a highly significant event for the civil litigation associated with a major commercial aviation accident. These findings are used by lawyers on both sides to pursue theories of liability or defenses that the NTSB factual and analytical reports suggest. Although the determination of potential liability is not part of the NTSB mission, the Safety Board's findings and conclusions offer such powerful statements on what caused an accident that conclusions about liability are inevitably drawn from them.

The NTSB's emphasis on probable cause as the ultimate finding from an investigation has been criticized by those who claim the statement is too accusatory or its scope is too limited. Current NTSB procedures call for probable cause to be summarized as part of the NTSB Final Report, but a full discussion of contributory causes is sometimes relegated to accompanying volumes of technical material. Other investigative bodies treat this material quite differently, generally including all causes or causal factors in one form or another. The NTSB has been inconsistent in the procedures it uses to report probable cause, sometimes issuing a single-paragraph statement, and other times issuing a comprehensive list of causal factors.

The Safety Board's factual findings and analytical conclusions are authoritative statements, and the statement of probable cause carries considerable weight in the aviation community. Lacking regulatory or enforcement authority, the NTSB's influential and highly public pronouncement of probable cause is one way the agency can play a central role in aviation safety.

Probable cause serves an important purpose and should be retained. Nevertheless, revising the procedures to identify all factors material to the cause of an accident and ranking them in terms of their contribution to the event would improve the quality of the NTSB's output. This is a more appropriate means of taking into account the complexity of many major accidents. Additionally, over time, a more complete picture of causal factors would be available to individuals responsible for planning and implementing safety programs. The consistent application of this practice would help make the NTSB's probable cause statement a more useful tool in the quest for improved air safety.

NTSB Resources Are Not Effectively Utilized

The management of resources in an agency as small as the NTSB is vitally important. Currently, the NTSB has no way to accurately measure how human resources are applied to a given accident investigation. Inadequate accounting information precludes any management of the human resources the NTSB has at its disposal. The NTSB relies on the

Department of Transportation (DOT) to process employee pay costs and therefore has no way to merge pay and nonpay accounts.

The adage "you can't manage what you can't see" aptly applies to current Safety Board practices. NTSB managers have little information they can use to plan the utilization of staff resources or manage staff workloads properly. The development of a real-time, full-cost accounting system would enable a project management function to emerge within the NTSB. Currently, NTSB senior managers cannot ensure efficient use of resources or adequately balance the workload among the myriad activities under way at any given time.

CONCLUSIONS

Although the NTSB has a need for additional resources and improvements to its internal systems and processes, the historical constructs upon which the agency was founded are basically sound. Alterations in the law are not needed to provide for the changes that must be made. The party process--the central organizational mechanism supporting air crash investigations--should continue to exist as an important source of vital information for the Safety Board. However, when the economic stakes in an accident are especially high, as they increasingly are, a greater risk exists for the party process to falter. In circumstances such as this, it is only prudent that the NTSB be prepared to augment the party process by securing technical expertise through alternative avenues.

The equivocal nature of the party process historically has been balanced by the NTSB's technical leadership; any potential erosion of the NTSB's base of expertise and any challenge to the strength of its professional staff are of great concern. Unfortunately, the NTSB is finding it difficult to conduct the training necessary to maintain technical proficiency and exercise leadership in accident investigations.

The main impediment to adequate training is the large workload, and the workload is not expected to suddenly lessen. The Safety Board will be called upon to resolve increasingly complex accidents and do so in the face of mounting scrutiny and rising economic stakes. It will

also become an increasingly visible aviation safety leader around the globe, supporting foreign investigations and playing a strategic role in reducing the risk of aircraft fatalities worldwide. There is also a need for the NTSB to adopt a more proactive posture with respect to accident prevention by studying *incidents* more carefully. Therefore, although the number of major airline crashes may diminish as the United States pursues an aggressive aviation safety agenda, the NTSB's workload will at best remain the same and most likely will rise.

It is clear that the NTSB needs additional human and facilities resources. An augmented workforce could provide greater flexibility, which in turn would support increased training. Changes in the administration, frequency, and amount of training are also vitally needed. Additionally, improvements to the NTSB's facilities are needed, both to meet the demands of future accident investigations and to enhance training opportunities.

Increased resources alone, however, will not ensure a renewed level of responsiveness and excellence at the NTSB. The Safety Board will need to adopt changes to its operation and processes while introducing a modern project-oriented information management system to efficiently and effectively manage its resources. Such changes are a prerequisite for monitoring the progress of other new initiatives.

The challenge is clear: The NTSB must substantially revise its practices, more closely manage its resources, and break out of the cultural insularity that is widening the gap between its staff and the rest of the aviation community.

RECOMMENDATIONS

RAND's recommendations are divided into eight proposed objectives designed to assist the NTSB in meeting future requirements for accident investigation. These recommendations are within the purview of the NTSB to implement without the need for legislation or new regulations. A more expansive set of recommendations can be found in Chapter 7 of this report.

Strengthen the Party Process

The NTSB must consider methods for augmenting the current party process model in order to provide access to independent analytical and engineering resources during the investigation of high-profile, highly complex accidents. This can be achieved without threatening the independence of the Safety Board and will help reverse a trend of the agency becoming increasingly isolated from the broader aviation community. The NTSB should not, however, augment the party system by including family representatives, plaintiff experts, insurers, or other individuals or organizations that have no direct involvement in identifying the technical cause of an accident.

Create a More Expansive Statement of Causation

The statement of causation is the Safety Board's most controversial output; it is crucial that this statement be as clear and complete as possible. The NTSB should view the probable cause statement not simply as the final investigative word on an accident but in a larger context--as a signpost supporting future aviation safety goals. To accomplish this, the NTSB should move away from simplistic, one-line probable cause statements and instead *consistently* adopt a comprehensive statement that reflects the reality that a modern aircraft accident is rarely the result of a single error or failure.

The probable cause statement should clearly state the principal event or failure that led to the accident. The probable cause statement should then also include all related causal factors. These causal factors should be ranked in terms of their contribution to the event, according to methods to be outlined in Safety Board investigative procedures.

Modernize Investigative Procedures

The NTSB must adopt strategies that successfully meet the challenge of modern air accident investigation, while reflecting a broadening investigative role. The NTSB should be better prepared to respond to complex accidents by reviewing the role and responsibilities of the IIC, possibly recasting this position into one of a project

manager, properly equipped with the tools required to manage lengthy and costly investigations.

Alternative team structures should also be studied to establish which ones are most effective when faced with complex accidents. The NTSB should take a more proactive stance in examining incidents, both to support far-reaching national goals and also ensure that its investigators are up to speed should a major accident occur. The NTSB should also undertake a comprehensive independent review of its existing statutory mandate to investigate all GA accidents, potentially leading to the legislative revision of this requirement.

Streamline Internal Operating Procedures

Several actions can reduce workload and improve the flow of investigative products. In particular, the current process for producing the Final Report should be less cumbersome and more visible to those who must ultimately approve the product--the Board members. The NTSB chairman and Board members should have the option of requesting a technical peer review of Final Reports and safety studies prior to their final review.

Strict time lines should be enforced for the preparation and release of Final Reports. The NTSB should lengthen its one-year baseline for major accidents to a more realistic 18-month baseline, with a 30-month maximum for any investigation. The current Board order describing the overall process for report preparation should be revised to include this time line and to allocate a greater percentage of the time to investigation and analysis than to report writing. Because so many of the Safety Board's operations depend upon information, efforts to manage the content, distribution, and quality of information should receive increased attention by the NTSB senior managers.

Better Manage Resources

Reducing the NTSB staff's workload is a prerequisite to improved training and more effective and timely completion of investigations. A key to success in this area is the development of management practices and tools that allow tracking the expenditure of resources. The NTSB must establish the requirements for management systems that achieve this

goal. Without such practices, little assurance exists that additional resources provided to the Safety Board will be most effectively employed. The NTSB should implement a system that permits full cost accounting of all Safety Board activities. This should be followed by the establishment of project management practices at all levels by assigning schedules and budgets to all investigations and safety studies.

Maintain a Strategic View of Staffing

The NTSB should continuously assess its long-range staffing requirements, taking into account the magnitude and nature of accident investigation demands, skill needs implied by the emerging fleet mix, and fluctuations in the labor market. Such a staffing plan should be made a Safety Board priority. Initially, the NTSB should seek an increase in the number of OAS technical staff of 12 to 14 percent over fiscal year 1999 levels to reduce excessive workloads, permit more time for training, and support the expansion of incident investigations.

The NTSB should explore the feasibility of sharing workloads through personnel exchange arrangements with other civil, military, and private centers with accident investigation expertise. The effects of aging staff on the NTSB's future skill mix, especially in terms of replenishment of critical expertise, should also be assessed. Finally, the NTSB's compensation structure should be reviewed to ensure that it is sufficient to hire and retain the necessary professional staff.

Streamline Training Practices

The NTSB must assign a higher priority to training a staff capable of unquestioned leadership during an investigation. In streamlining existing training programs, the NTSB's senior staff must create a balanced training program that builds management skills, professional capabilities, and investigative expertise. The first step should be the creation of a baseline training plan that establishes standards for each major job title.

The NTSB should also create a full-time training officer position to build and maintain the training plan. The NTSB general counsel should clarify the NTSB's policy regarding gratuities in relation to the

acceptance of training opportunities offered by private corporations and other government agencies. Finally, the NTSB should emphasize cross-training whenever possible to build multidisciplinary capabilities, while also taking steps to preserve the technical expertise of staff in key disciplines.

Improve Facilities for Engineering and Training

The NTSB should review its internal technical capacity to support future accident investigations, including the potential for crash reconstruction and the requirements for system testing in support of complex accident investigations. The Safety Board's long-term facilities requirements should reflect the fact that facilities can serve a dual function, and should therefore include consideration of using them for staff training. To conduct this review, the NTSB should commission an external study that looks at technical and training requirements for the next 15 to 20 years for all transportation modes. The NTSB should also improve its technical ability in the areas of modeling and simulation.

The NTSB has become a critical link in the chain that ensures the safety of the traveling public in the United States and throughout the world. That link cannot be allowed to weaken. Unless purposeful steps are taken to modernize the internal workings of the NTSB, supplement its overloaded workforce, and enhance the resources and facilities available to its investigative staff, the continued vitality of the NTSB cannot be guaranteed. It is in the interest of everyone who travels, by whatever mode, to ensure that the NTSB continues to set the world standard for independent accident investigation.

CHAPTER 1

INTRODUCTION

The NTSB is pivotal to the safety of the traveling public in the United States and throughout the world. Although it is not a regulatory agency and does not command significant enforcement powers, the NTSB exerts enormous influence based on the independence and accuracy of its accident investigations and the authority of its recommendations. The NTSB is charged with the responsibility for investigating and establishing the facts, circumstances, and probable cause of transportation accidents and making safety recommendations to governmental agencies to prevent similar accidents from happening in the future.

Fundamentally, the Safety Board provides a quality assurance function vital to the ongoing safety of all modes of transportation. The NTSB's unique role in transportation safety is contingent on the ability of the board members and the professional staff to conduct independent investigations of accidents and major incidents and, in so doing, to assure public confidence in the safety of our national transportation systems.

The NTSB has become most publicly identified with its investigations of major commercial aviation accidents. The NTSB has the responsibility for investigating every civil aviation accident in the United States. In addition, based on the agency's mandate under Annex 13 to the Convention on International Civil Aviation (known as the Chicago Convention) and related international agreements, the NTSB participates to a greater or lesser degree in the investigation of commercial aviation accidents throughout the world.

The NTSB enjoys a worldwide reputation as "the best in the business," but it cannot afford to run in place. NTSB investigators are going to be asked to unravel increasingly complex accidents in an environment beset by high-stakes litigation and intense public scrutiny. In recent years, the NTSB has undertaken aircraft accident investigations of unprecedented cost, complexity, and length,

exemplified by such high-profile accidents as TWA Flight 800 and USAir Flight 427. These investigations have stretched staff resources to the limit and have seriously challenged the expertise of NTSB investigators.

The integrity of the NTSB's accident investigation process depends on the independence and skills of the agency's investigative staff, combined with the accuracy and thoroughness of the information provided by the organizations, corporations, and individuals designated to assist as "parties" in investigative proceedings. The Safety Board's principal resource is its staff. Consequently, workload, staffing, and training are key determinants of the agency's competence and proficiency. Constraints on budget, personnel, and technical resources have already posed a fundamental challenge to the agency's ability to do its job.

The continuation of "business as usual" will simply not be enough to ensure fulfillment of the NTSB's critical safety mission. The NTSB must embrace new methodologies, new management approaches, and a new awareness of its working environment if future demands and expectations are to be met.

This report addresses a number of issues relevant to the investigation of major commercial aviation accidents and outlines a specific agenda of actions to bolster the NTSB's independence and to ensure that the safety board has sufficient resources to effectively investigate the kinds of accidents that are likely to occur well into the 21st century.

A NATIONAL FOCUS ON AIR SAFETY

On July 17, 1996, TWA Flight 800 with an early model Boeing 747 carrying 230 passengers and crew lifted off from New York's John F. Kennedy International Airport bound for Paris. Minutes later, the huge airliner exploded and crashed into the waters off the eastern shore of Long Island. The terrific force of the explosion had torn the aircraft apart, and the disturbing recovery images, along with vivid eyewitness accounts, riveted the attention of a shocked American public for many weeks.

It was an all too familiar scene. Only two months earlier, a McDonnell-Douglas DC-9 operated by ValuJet Airlines had slammed into the

Florida Everglades killing 110 people. With the aircraft on fire and losing control, the crew struggled to land the crippled airliner. The crash scene was particularly gruesome.

These back-to-back crashes shook the foundation of the aviation community. The traveling public was frightened, and media pundits questioned the perceived safety of domestic airline operations.

The Clinton administration reacted quickly. On July 25, 1996, President Bill Clinton announced the creation of the White House Commission on Aviation Safety and Security.¹ Chaired by Vice President Al Gore, the commission set an aggressive agenda for reviewing the safety of the air transportation system and issued initial recommendations within two months. The final report, issued five months later, outlined sweeping changes calling for regulatory reform and additional research directed toward new and safer technologies. Most important, the commission's report prescribed a national goal of dramatically reducing the risk of fatalities in the air (Office of the President of the United States, January 1997).²

Concerns over aviation safety expressed in the White House commission's report were echoed by the report of the congressionally mandated National Civil Aviation Review Commission (popularly known as the Mineta Commission, chaired by former California Congressman Norman Mineta), issued in December 1997 (National Civil Aviation Review Commission, December 11, 1997). The report highlighted an industry analysis showing that existing accident rates and increasing demand for air travel could lead to an airline accident occurring somewhere in the world on a weekly basis. Clearly, aviation safety was a matter requiring renewed U.S. leadership and significant national investment.

¹Initial concerns that an explosive device or terrorist activity had caused the crash of TWA Flight 800 prompted an early focus on the security aspects of aviation safety.

²The actual goal, embraced and refined within the FAA's Strategic Plan, aims to "reduce the U.S. aviation fatal accident rate per aircraft departure, as measured by a three-year moving average, by 80 percent from the three-year average for 1994-1996" by 2007. An aircraft manufacturers group, the Commercial Aviation Safety Team, has joined the FAA in pursuit of this goal (Federal Aviation Administration, May 1998, p.2).

At the same time, the newly enacted Aviation Family Assistance Act of 1996 mandated the creation of the Task Force on Assistance to Families of Aviation Disasters, overseen jointly by the U.S. DOT and the NTSB. The TWA and ValuJet disasters had also unveiled the urgent need to find ways to improve the treatment of victims' families by the government, the airlines, the legal community, and the media. Among other things, the White House commission requested that the task force review the accident investigation process utilized by the NTSB and its potential impact on families. The task force's report, containing 61 separate recommendations, amounted to a blueprint for the appropriate treatment of families suffering such grievous losses (U.S. Department of Transportation and the National Transportation Safety Board, 1997).

Noteworthy among the task force's recommendations was a directive to the NTSB to "formally review" the party system, an essential element of the agency's investigative process, which allows the companies and entities involved in the accident to participate directly in the NTSB investigation.

THE ROLE OF THE NTSB IN AVIATION SAFETY

From the perspective of the NTSB, the combined effect of these successive commission and task force reports was significant, raising important questions about the future mission and workload of the NTSB, as well as concerns about the agency's investigative methods and operations.

The NTSB's mission is primarily *proactive*--the prevention of transportation accidents--yet the agency accomplishes this mission primarily by being *reactive* in responding to catastrophic events. The NTSB's goal is to improve quality (safety and performance) through the analysis of failure (the crash of an aircraft). When defects are found, the NTSB issues recommendations that can have profound effects on how aircraft are designed, manufactured, and operated.

Because U.S.-made aircraft are sold and operated worldwide, suggested improvements from the NTSB have international implications for air safety. Over the years, the NTSB's many safety recommendations, synthesized from tragic events, have helped bring the performance of the

National Airspace System (NAS) to its current state of high performance and reliability.

Following the crash of Korean Air Flight 801 in Guam on August 6, 1997, killing 228 passengers, no fatal domestic commercial aviation accidents took place until the June 1, 1999, crash of an American Airlines MD-80 airliner in bad weather in Little Rock, Arkansas, killing 11 people.³ This 22-month hiatus in major accident events lulled some policymakers into believing that issues related to aviation safety, at least on the domestic front, had been adequately addressed. Whether this pause in fatal accidents was due to increased government and industry vigilance, or simply the highly stochastic nature of aircraft accidents, will never be known.

However, even if aviation accidents become relatively rare events, the role of aviation accident investigation is germane to this study. What will the NTSB investigate if fewer planes crash? Of course, the NTSB investigates accidents in all transportation modes, but the lion's share of its efforts and its public identity are tied to aviation. The answer to this mission-related question could fundamentally change the form and function of the NTSB in the years ahead.

Both inside and outside the NTSB, concerns have also been expressed that the safety board is becoming fragmented and is operating at the limits of its capability. In recent years, the NTSB has undertaken aircraft accident investigations of extraordinary cost, complexity, and length. The investigation of the crash of TWA Flight 800 is still not complete, almost four-and-a-half years later as of this writing. The investigation of another high-profile accident, the crash of USAir Flight 427 in 1994, took more than four years to complete, yielding a conclusion that was technically controversial and circumstantial.

These crash investigations mark some clear trends. They demonstrate that when modern airplanes--machines developed with highly integrated systems and high orders of complexity--crash, the subsequent

³During the 22-month period following the crash of Flight 801, several major commercial aviation accidents occurred worldwide, most prominently the crash of Swissair Flight 111, involving a McDonnell-Douglas MD-11, near Halifax, Nova Scotia, killing 229 people traveling from New York to Geneva, including 137 Americans.

investigation is likely to involve commensurate levels of complexity. NTSB investigators can quickly become the target of intense media attention and face new sources of criticism and alternative accident theories, especially those flooding in via the Internet.

Finally, the economic stakes have never been higher. Today, a major accident can expose manufacturers and operators to enormous potential losses. Companies suffer costly mandated repairs and modifications to aircraft or operating procedures, multimillion dollar liability claims, and the loss of international market share. The magnitude of potential loss can be so high as to call into question the commitment of private parties to full disclosure and technical objectivity during investigations. Because the NTSB has historically depended on the openness of private firms involved in a crash, any change in behavior would significantly affect safety board investigative practices and organizational capabilities.

These factors combine to bring into focus the technical practices, staff capabilities, and operational methods of the NTSB. Can the NTSB, as currently chartered and operated, deal with modern aviation accidents? Can its traditional relationships with stakeholders in the aviation community continue to operate reliably in such a highly litigious environment? These questions make it clear that the NTSB is facing a period of dramatic change. Such realities motivated RAND's detailed review.

OBJECTIVES OF THE STUDY

The chairman of the NTSB asked RAND to address two important issues at the heart of the NTSB investigative process: the Safety Board's interaction with external parties during an investigation and the ability of its internal staff to be trained to meet existing and emerging challenges. These issues are closely related, as the research came to clearly demonstrate. Ultimately, RAND's analysis looked closely at the internal operations of the NTSB and carefully examined its relationship with outside stakeholders in the aviation community.

Leadership is a central theme of NTSB operations, providing the essential connection between staff capability and the ability to manage

and direct major investigations. From its inception, the Safety Board was viewed as an agency to lead accident investigations, in concert with the outside parties involved in a crash--that is, the airline, the aircraft manufacturers, air traffic control, airport operators, and others. This is the essence of *the party process*. It is the core *modus operandi* for the NTSB's investigation of all transportation accidents.

The centrality of the party process reflects an appreciation, on the part of legislators and other policymakers, that an agency capable of operating with complete autonomy would be impossibly large, unwieldy, and costly considering the diversity of accidents that the Safety Board is called upon to investigate. The NTSB must work with parties involved in a crash because its in-house expertise is not sufficient. However, this presents a clear and present danger to the integrity of the investigative process--parties that face potentially enormous economic losses if they are found to be the cause of an accident could attempt to disrupt or bias an investigation.

Two basic tenets underpin this somewhat risky policy choice:

- The Safety Board staff must manifest exceptional skill and expertise, combining leadership in relevant technical areas with superior investigative talents and management abilities. The NTSB's principal resource is clearly its staff. How this staff is recruited, maintained, and trained ultimately ensures, more than any other factor, the timely and accurate resolution of transportation accidents.
- The parties to an accident investigation will participate openly, honestly, and with the highest level of integrity, prompted by the notion that safety will be furthered by the expeditious determination of the cause of an accident.

Although the second of these principles is necessary to fulfillment of the NTSB's investigative goals, it is not sufficient in the absence of the Safety Board's exercise of leadership through the excellence and expertise of its staff. Should either tenet be violated, the credibility of the Safety Board's product--that is, the findings of cause and safety recommendations--would become suspect. RAND's research can be summarized as a review of these two fundamental tenets of NTSB operations.

The research examined two aspects of the agency's operations:

- NTSB practices and policies with regard to the training and qualifications of aviation accident investigators, including a determination of the adequacy of such policies and practices in light of future technological developments in aviation.
- The functioning of the party process as a means of supplementing NTSB skills and technical knowledge, including an examination of the liability environment in which the party system operates.

It is important to note that a strong feeling of general concern about the NTSB surrounded these specific research objectives. RAND encountered a consistent uneasiness regarding the ability of the NTSB to generate timely and accurate results. Many observers and stakeholders openly expressed a belief that the NTSB's technical capabilities had been seriously eroded and that investigations were being hampered by an overloaded staff that was increasingly insulated from the aviation community.

Individuals inside and outside the NTSB expressed these concerns. Many stakeholders cited, for example, growing tension between the NTSB and aviation regulators at the FAA. Others expressed concern that the NTSB's limited staff was no match for the opposition--large commercial firms facing huge potential losses. Inevitably, the information acquired during the course of this research, as well as the resulting findings and recommendations, expanded to incorporate some of these broader questions.

RAND worked with NTSB senior managers specifically to augment the scope of the research in selected areas. For example, while original study objectives called for an examination of NTSB training policies, it quickly became apparent that maintaining a capable staff does not depend only on training but is also influenced by hiring policies and staff workloads. The scope of work was subsequently expanded to address hiring and workload issues. In the course of the research, RAND also noted many areas in which internal NTSB practices either inhibited the hiring and training of staff, added to an already heavy workload, or caused

breakdowns in communication with parties involved in investigations. These issues are summarized in this report.

The breadth of the research should also be noted. Resource limitations demanded that RAND focus its analysis on aviation accidents, largely ignoring the four other areas of NTSB authority.⁴ Many of the observations made in this report have relevance to these other modes of transportation; however, wholesale extrapolation of the findings and conclusions of this report beyond the sphere of aviation should be avoided. Where possible, RAND has attempted to identify areas applying to the NTSB at large.

Finally, the depth to which these objectives could be explored was, of course, limited by funding. Some aspects of the research could only be touched upon, leaving others inside or outside the NTSB to expand upon the themes RAND identified. In such cases, RAND characterized the issues for the NTSB and recommended additional research and analysis with more focused objectives.

RESEARCH APPROACH

A study of this magnitude clearly pointed to the need for a multidisciplinary research approach. RAND selected personnel from several different RAND programs, including the Institute for Civil Justice, the Science and Technology Policy Institute, and Project AIR FORCE. The project's staff included aeronautical engineers, public policy analysts, and an attorney to address the diverse set of issues the NTSB presented.

The analysis examined external factors influencing NTSB operations such as the volume and type of accidents, advances in technology, and the legal environment, and internal factors such as the policies and procedures the NTSB follows to staff and train its workforce and to conduct its investigations.

⁴The Safety Board also investigates accidents involving (1) railroads; (2) interstate buses, interstate trucking, and other highway accidents selected in cooperation with state authorities; (3) pipelines and hazardous materials; and (4) marine accidents (in conjunction with the U.S. Coast Guard).

RAND created a five-phase research plan to identify critical issues and illuminate the various challenges facing the NTSB. The analysis created a historical perspective of the NTSB and exhaustively studied current procedures and capabilities. Proposed solutions must, however, provide the NTSB with the flexibility it needs to meet future demands and the changing nature of air accidents. With this in mind, RAND paid close attention to the environment in which the NTSB will operate in the future. The five phases of the research plan consist of

- **Baseline development**--the analysis of information about the NTSB's operating budgets, staff size, accident volumes, and duration of investigations
- **Emerging environments**--an assessment of how the aviation environment is likely to change and how the changes could shape NTSB operations
- **Liability environment review**--an examination of the current civil legal system as it affects the settlement and litigation of aviation accident cases and the behavior of stakeholders in the party process
- **Staffing and training review**--an analysis of current staffing and workloads and the state of accident investigator training
- **Internal process review**--a critical assessment of the internal management and operating processes in use at the NTSB.

RAND quickly determined that the NTSB had a limited amount of quantitative data. These data were often of insufficient fidelity to support analyses of the magnitude intended in the research plan. The research team acquired as much NTSB financial and staffing data as could be obtained through a reasonable expenditure of project funds. The team also acquired accident statistics and information about the status of investigations and integrated that information to form an initial baseline characterization of the Safety Board.

RAND used internal NTSB records on personnel, workload, training, budgets, accidents, and accident reports to characterize NTSB operations. Typically, these records could not be used directly and had to undergo a considerable amount of processing before they could be

employed to answer research questions. To augment the NTSB's quantitative data, RAND relied on the following research methods:

- **Structured questionnaire.** RAND created a confidential survey instrument and distributed it to all professional staff (not limited to aviation) at the NTSB headquarters in Washington, D.C., and the NTSB's field and regional offices. Quantitative analysis of the responses to this questionnaire provided additional information about the NTSB staff that standard management information systems do not normally capture. Results were subjected to statistical tests to characterize the degree of uncertainty arising from the response rate.⁵
- **Structured interviews.** RAND interviewed board members and senior management and technical staff at the NTSB's headquarters and regional offices. Representatives from a broad cross section of stakeholders in the aviation community were also interviewed, including defense and plaintiff attorneys, insurers, air safety educators, air carriers and GA manufacturers, airline training personnel, aviation researchers, union representatives, families of accident victims, government regulators and policymakers, Canadian and European accident investigators, and European aircraft manufacturers.
- **Legal review.** RAND reviewed available legal materials related to the NTSB investigative process, including applicable federal regulations, published and unpublished judicial opinions, legal treatises, and legal periodical materials.
- **Site visits.** In addition to frequent visits to NTSB facilities, RAND visited the reconstruction of TWA Flight 800 at the NTSB site at Calverton, New York; National Aeronautics and Space Administration (NASA) research facilities; large and small aircraft manufacturing sites; flight simulation facilities; and

⁵For a more complete description of the RAND skills and experience questionnaire administered to the NTSB staff and a detailed analysis of the survey results, see Appendixes D and E of this report.

aviation safety schools to gain firsthand knowledge of the environment in which accident investigations take place.

- **Case studies.** RAND selected a set of case studies to review NTSB procedures and practices. Accidents were selected that taxed NTSB resources, either technically or organizationally.⁶
- **Workshops.** Three workshops were held with stakeholders from government and industry, senior government aviation officials, and families of accident victims to discuss many disparate viewpoints. These workshops were conducted without attribution to facilitate the free exchange of information.

Additionally, RAND relied on extensive telephone interviews, an exhaustive literature review, and extensive use of Internet-based quantitative and qualitative data to augment the methods listed earlier.

Collectively, the numerous data sources provided a rich set of information with which to perform case studies and other more quantitative data analysis that addressed project objectives.

⁶A list of the accident investigations in the case study set can be found in Appendix F.

CHAPTER 2

THE NTSB'S ROLE IN AVIATION ACCIDENT INVESTIGATION AND NTSB'S OPERATIONAL BASELINE

This chapter provides a primer on the NTSB's investigative procedures and describes the baseline data upon which RAND based its analysis. This background information establishes a framework for the findings and recommendations that appear in Chapters 3 through 6 of this report. The description of the accident investigation process is intended to be informative, but not definitive, because the details of this process are discussed in much greater detail in later chapters. For readers not familiar with the history and regulatory authority of the NTSB, RAND has provided a brief background on the agency in Appendix A.

INVESTIGATING A MAJOR COMMERCIAL AVIATION ACCIDENT

Accident or incident investigations are conducted by the NTSB to determine "as accurately and expeditiously as possible what caused the accident so that the necessary steps can be taken to guard against" a similar occurrence (National Transportation Safety Board, April 25, 1980). These investigations are intended to be fact-finding proceedings in which no formal issues are addressed and no adverse parties are involved. They are not subject to the provisions of the Administrative Procedure Act¹ and are not conducted for the purpose of determining the rights or liabilities of any person or company.²

The NTSB investigates both "accidents" and "incidents." An *accident* is defined as "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, in which any person suffers death or serious injury (hospitalization for more than 48 hours, fracture of a bone, severe hemorrhage, nerve or muscle damage, second or third degree burns), or in which the aircraft receives substantial damage." *Substantial damage* consists of damage or failure which "adversely affects the structural

¹5 USC §504 et seq.

²49 CFR §831.5.

strength, performance, or flight characteristics of the aircraft and which would normally require major repair or replacement of the affected component" (National Transportation Safety Board, April/May 1998a). An *incident* involves an occurrence other than an accident "which affects or could affect the safety of operations."

Every aviation accident or incident investigation falls within one of five categories:

- **Major investigation.** This usually entails an accident involving a commercial airliner or cargo aircraft. The Washington headquarters of the NTSB, through the OAS dispatches a "go-team" of investigators to handle the investigation of such an accident.
- **Major investigation, regional office.** This is a less serious air accident in which significant safety issues have been identified. It is handled by one of the NTSB's six regional offices, at least at the outset. Some nonfatal airline accidents and most small commuter airline accidents fall into this category.
- **Field investigation.** This is an airline accident or incident with no fatalities (such as an incident involving air turbulence) or a GA accident. The investigation is conducted by the nearest regional office and at least one investigator goes to the site of the accident. A small number of field investigations involving GA aircraft are complex and grow to rival headquarters-led investigations.
- **Limited investigation.** A limited investigation, sometimes called a "desk investigation," is conducted subsequent to an event involving GA aircraft. This investigation is carried out by U.S. mail or over the telephone.
- **Delegated investigation.** These investigations are delegated to the FAA. They include accidents involving rotorcraft, amateur-built aircraft, restricted category aircraft, and all fixed-wing aircraft that have a certificated maximum gross takeoff weight of 12,000 pounds or less, *unless* fatalities occurred, the aircraft was operated as an "air taxi," or the accident

involved a midair collision. The FAA is directed to report the facts, conditions, and circumstances of the accident to the NTSB; if necessary, the Safety Board may determine the probable cause.

When a major commercial aviation accident occurs, an NTSB "go-team" led by an IIC is dispatched from the agency's Washington, D.C., headquarters to the accident site, usually within two to three hours of notification of the event. The IIC--a senior air safety investigator with NTSB's OAS--organizes, conducts, and manages the field phase of the investigation, regardless of whether a Board member is also on scene at the accident site.³ The IIC has the responsibility and authority to supervise and coordinate all resources and activities of all field investigators.

Often, an investigator from one of the NTSB regional offices arrives on the scene in advance of the go-team. This individual begins the investigation and coordinates site security and other matters while awaiting the arrival of the go-team. The first job of the IIC is to secure the evidence and conduct an audit to ensure the safety of the area by noting any hazardous cargo, fuel spillage, and fire hazards. Once at the scene, the IIC is responsible for the security and management of the crash site. The IIC and key NTSB personnel usually take a tour of the site and receive an initial briefing from local officials. Until the investigative team is organized, everyone else is restricted from the scene.

The NTSB go-team forms discipline-oriented investigative groups, each led by a "group chair" and overseen by the IIC. The group chairs are senior investigators who are specialists in, among other areas of study, power plants, systems, structures, operations, air traffic control, weather, survival factors, and human performance. An aircraft performance specialist is assigned to most investigations and an NTSB specialist is often assigned to interview witnesses and review maintenance records. All NTSB staff that are assigned to an

³49 CFR §831.8.

investigation work under the direction of the IIC while at the accident scene.

The Party Process

The "party process" allows the NTSB to leverage its limited resources and personnel by bringing into an investigation technical expertise from the aircraft manufacturers or airlines, professional organizations (such as the Air Line Pilots Association [ALPA]), and individuals who were involved in the accident or who might be able to provide specialized knowledge to assist in determining probable cause.

The NTSB maintains the team approach throughout the on-scene phase of the investigation, with teams consisting of staff from both the parties and the NTSB. Shortly after arriving at the accident site, the IIC convenes an organizational meeting, usually at a large hotel or nearby facility where the NTSB command post is established. At that meeting, each party to the investigation--such as the FAA, air carrier, airframe manufacturer, engine manufacturer, the ALPA, and the airport authority--designates a spokesperson or coordinator who is responsible for supervising its specialists on the NTSB team. Each party coordinator is expected to report to and respond to the IIC's directions, and ensure that all personnel from the organization comply with NTSB rules and procedures.

The party process is a fundamental component of the NTSB investigative process (this is discussed further in Chapter 4). Except for the FAA, which by statute is allowed to participate in every investigation, party status is a "privilege" and not a "right."⁴ The IIC has the discretion to designate which parties are allowed to participate in the proceeding. No members of the news media, lawyers, or insurance personnel are permitted to participate in any phase of the investigation, including any meetings. Claimants or litigants (victims or family members) are also specifically prohibited from serving as party members.

According to NTSB procedures, the IIC works with selected insurance representatives, in conjunction with the aircraft owner, for the purpose

⁴49 USC §1132.

of retrieval, movement, and release of the wreckage. The IIC or the on-scene Board member also holds occasional press conferences to report the status of the investigation to the media.

The specialists assigned by any party to an NTSB investigation must be employees of the party and must possess the expertise required to assist the NTSB in its investigation. The NTSB regulations state, in part, that "parties to the field phase shall be limited to those persons, government agencies, companies, and associations whose employees, functions, activities, or products were involved in the accident or incident, and *who can provide suitable qualified technical personnel to actively assist in the field investigation* [emphasis added]." ⁵

Every participant in the Safety Board's investigation must be in a position to contribute specific factual information or skills that would not otherwise be available to the Safety Board. *A Guidance for Party Coordinators*, published by the NTSB's OAS, further warns that no participating organization is permitted to be represented by a person whose interests lie beyond the safety objective of the accident investigation (National Transportation Safety Board, March 1994a).

Specialists assigned to investigative groups are required to work under the direction of the appropriate NTSB group chair at all times. Party status provides representatives access to daily progress meetings that are not open to the public or to the victims, their families, or their lawyers. As a result of providing the Safety Board with technical assistance, parties are given numerous opportunities to learn exactly what happened during an incident and to assist in directing the search for answers.

The transmission of information by private parties back to their corporate headquarters is to take place only with the consent of the IIC when the information is necessary for accident prevention purposes. The information is not to be used in litigation or for public relations purposes. Sanctions for failing to abide by the NTSB rules and procedures include the dismissal of individuals and the parties they

⁵49 CFR 831.11(a).

represent from the investigation team. Party representatives sign a written statement indicating that they are familiar with the NTSB rules and that they agree to abide by the regulations.

The Team Approach

As investigative groups are formed during the organizational meeting, each party, or its accredited representative, is permitted to assign its experts to the respective groups to assist in the investigation. For example, the air carrier typically assigns a training pilot who is type-rated in the kind of airplane involved in the accident to the Operations Group. Similarly, the aircraft manufacturer would assign a test pilot to the Operations Group and systems or structural engineers to the Structures, Systems, or Powerplants Groups.

If the aircraft is equipped with a cockpit voice recorder (CVR) and flight data recorder (FDR), special groups led by NTSB specialists are formed in Washington, D.C., to process the recorder readouts. Membership in the FDR and CVR groups is strictly limited and tightly controlled because of the sensitive nature of the data obtained. Party status to an NTSB investigation does not automatically allow the assignment of personnel to all of the investigative groups.

The on-scene phase of the investigation may last from 7 to 21 days. Each person assigned to the NTSB team comes prepared for extended work schedules, often under extremely stressful conditions that are both physically and mentally taxing. To maintain continuity and maximize the utility of the team concept, substitution of any individuals in a group is highly discouraged, and no "independent" investigations by parties or group members are permitted.

As the on-scene phase of the investigation comes to a close, each group chair prepares "field notes" that contain the factual findings and other data collected by the group. Group notes contain entries such as interview summaries, wreckage diagrams, cockpit documentation lists, damaged component descriptions, photographs, video or audio tapes, and other such materials.

The field notes are the only official representation of conditions immediately following an accident. They are very important because a

witness's memory of events can change with time and the wreckage itself can be altered shortly after the on-scene phase of the investigation is completed. Each group member has an opportunity to review and comment on the field notes and receives a copy of the notes before the group disbands. Factual discrepancies are resolved, corrected, or annotated as dissenting opinions. Each party coordinator receives a copy of all the field notes before the team leaves the site. The parties' group members and coordinators are obligated to remain with the team until the close of the field phase of the investigation, or until they are released from their duties by the NTSB group chair or the IIC.

After the on-scene phase concludes, each of the NTSB group chairs completes a final factual report covering his or her area of responsibility. All factual material is sent to the party coordinators and is placed on the public docket. At that point, a technical review meeting is convened to allow the parties one final opportunity to comment on the quality and scope of the factual record.

PUBLIC HEARINGS AND ACCIDENT REPORT PREPARATION

Following the on-scene phase of the investigation, the investigators begin a rather lengthy period of further fact gathering, often involving one or more public hearings, and a final analysis of the facts that have been collected. This process eventually results in a publicly available printed report that, barring reconsideration at a later date, is the NTSB's final product from an investigation. The Final Report (or "Blue Book") includes a list of factual findings pertaining to the accident, an analysis of those findings, recommendations to prevent a repetition of the accident, and a probable cause statement.⁶

Shortly after the investigation team returns to NTSB headquarters from the accident site, a tentative schedule of follow-on events is established by the IIC. Theoretically, these events should occur over a period of six months, but no time limit exists on NTSB investigative activity. Safety Board procedures call for a targeted publication date of the Final Report to be within one year from the date of the accident,

⁶The terms "Final Report" and "Blue Book" are used interchangeably throughout this report.

but recent major commercial aviation accident investigations have taken as little time as four months and as much as four-and-a-half years (National Transportation Safety Board, October 9, 1998).

Follow-Up Activities

The report-writing process begins with a work planning meeting. This is an internal meeting of the Safety Board group chairs and senior staff, chaired by the IIC. During this meeting, the staff determines which investigative activities remain, including testing, follow-up interviews with witnesses or survivors, and so on. The need for interim and/or urgent safety recommendations is also discussed.

A Factual Report due date is set during the work planning meeting to target the completion time of the final factual reports by the group chairs. Often, a professional writer is assigned to assist with assembling the factual reports and turning them into the Safety Board's Final Report. Non-NTSB investigative group members have an opportunity to review and comment on the draft factual reports prior to the target date. When completed, the factual reports are mailed to all the parties to the investigation.

If it is decided that the investigation warrants a public hearing, parties to the hearing attend a pre-hearing conference. At this meeting, ground rules for proper conduct and questioning are outlined and the areas for questioning are discussed. This is the last formal opportunity for parties to request that certain subject areas be explored, specific witnesses interviewed, or any new exhibits be included in the record.

A public hearing is another step in the Safety Board's fact-gathering process. Major commercial aviation accidents that involve significant loss of life and raise important safety issues, thereby warranting public and media attention, usually call for a public hearing. However, the decision to hold a hearing is discretionary and is not subject to review.

A public hearing is a proceeding during which witnesses are questioned under oath by the IIC and the NTSB group chairs. The witness list can include FAA regulators, surviving crew members or passengers, air traffic controllers, fire and rescue personnel, manufacturers'

design engineers, and others. The hearing is usually held in a city near where the accident occurred, and is directed by an NTSB Board member who is designated as the presiding officer. Each party coordinator may query the witnesses after their initial questioning by the NTSB technical staff, although no party may be directly represented by anyone who "occupies a legal position." Any individual who appears in person to testify at a public hearing has the right to be represented or advised by counsel, but no party may be represented by anyone who also represents claimants or insurers.

On the first day of the hearing, all factual reports generated to that date, including the CVR transcript, are entered into the public docket for the accident. The public docket is the formal collection of documents relating to the investigation, and is open and available for public review. Because the factual reports are publicly released at this time, parties are permitted to communicate with the media about the accident.

Testimony and statements during the hearing, which can take up to three or four days, are transcribed by a court reporter and transcripts become available to the public within a few weeks. Such hearings are fact-finding proceedings with no formal issues being addressed and no adversary parties participating, and the hearings are not subject to the provisions of the Administrative Procedure Act.⁷

The next milestone in the accident investigation process is the preparation of factual reports in which each group chair summarizes the facts that have been gathered concerning his or her area of expertise. Parties may contribute to these reports via their continued interaction with the NTSB group chairs and the IIC, but parties are not allowed to formally review, edit, or comment on the factual reports themselves. Party coordinators may, however, be invited to attend a technical review meeting with the IIC, the group chairs, and NTSB supervisors to review aspects of a factual report prior to its completion.

Parties to the investigation can provide input on the Safety Board's overall analytical process through what are called "party

⁷See 49 CFR §845.1-845.29.

submissions." All parties are encouraged to submit to the Safety Board written observations and findings and recommend conclusions based on the evidence produced during the investigation. These party submissions become part of the public docket of the investigation.

The IIC is nominally responsible for integrating the factual reports into a Final Report that includes a summary, a set of conclusions, and a set of recommendations. The IIC distributes an internal first draft of the Final Report to the group chairs and NTSB supervisors to solicit their feedback. The internal draft is then distributed to the directors of the OAS, the Office of Safety Recommendations, the Office of Research and Engineering (ORE), the general counsel, and the NTSB managing director for comments and any necessary corrections. After this review of the draft is complete, the NTSB directors schedule a closed meeting to discuss the report's content and organization.

Notation Draft and Board Meeting

The draft produced by the directors becomes the *notation draft*--the final version of the report that is presented to the five members of the NTSB Board of Directors. Board members have a limited time to review the draft in preparation for a final vote on the finding and recommendations. Written submissions from parties to the investigation are not accepted after the Board receives the notation draft. However, personal contact with individual board members is permissible.

Following review of the report by the Board, a public meeting, sometimes referred to as the "Sunshine Meeting," is held in Washington, D.C. The NTSB staff, including the IIC and the group chairs, present the Final Report and comment on it before the Board. Party representatives may attend this meeting but are not permitted to comment or make presentations. At this public meeting, board members may elect to do any of the following:

- vote to adopt the draft, in its entirety, as the final accident report
- require further investigation or revisions

- adopt the final accident report with changes that are discussed during the meeting.

As soon as possible after the meeting, the NTSB's Office of Public Affairs releases the Safety Board's conclusions, probable cause determination, and safety recommendations. The Final Report, which may be hundreds of pages long, is published approximately three weeks after the Safety Board meeting.

Although the publication of the Final Report is the last step in the investigative process, NTSB investigations are technically never closed. Parties to the investigation can petition the Safety Board to reconsider and modify the findings and probable cause of the accident for either one of two reasons: (1) the party believes the Safety Board's findings are erroneous, and that the Safety Board made a mistake in its analysis during its original assessment of probable cause; or (2) the party discovers new evidence. The NTSB will not consider petitions from parties that have not made submissions during the investigation, or that repeat positions previously advanced. Parties can petition the NTSB to reconsider the findings and probable cause at any time after the Board meeting and adoption of the Final Report. Reconsideration proceedings normally involve written, not oral, presentations.⁸

INTERNATIONAL ACCIDENT INVESTIGATIONS

The NTSB's role in investigating aviation accidents that occur outside the United States is somewhat different from its role in investigating domestic accidents. The NTSB is the government agency charged with the responsibility for assuring compliance with U.S. obligations under Annex 13 to the Convention on International Civil Aviation. This international treaty, signed by 52 nations in December 1944 and commonly known as the "Chicago Convention," established the

⁸49 CFR §845.41 sets forth the rules for petitions for reconsideration or modification. This provision allows for petitions for reconsideration to be filed by "other person[s] having a direct interest in the accident investigation." While this language seems to afford nonparties, such as family representatives, the right to file for reconsideration, this is not the interpretation generally applied by the NTSB (Campbell, April 1999).

International Civil Aviation Organization (ICAO), headquartered in Montreal, Canada.

With its 183 member nations, the ICAO provides the governing apparatus for worldwide regulation of civil aviation. The objectives of ICAO are to develop the principles and techniques of international air navigation and foster the planning and development of international air transport. Over the years, the ICAO governing body, the Council, has developed and adopted 18 technical annexes to the Chicago Convention, which deal with such varied fields as aeronautical communications, airworthiness, environmental protection, and security. The standards contained in these annexes are applied universally, and have produced a degree of technical uniformity that has enabled international civil aviation to develop in a safe and efficient manner (McCormick and Papadakis, January 1996).

Standards and recommended practices for aircraft accident investigations were first adopted by the ICAO in 1951, pursuant to Article 57 of the Chicago Convention, and were designated "Annex 13" to the Convention. The annex contains standards for accident prevention and for incident and accident investigation and reporting. Under Annex 13, the sole objective of an investigation is to prevent future accidents or incidents, and not to attach blame or liability.

Specifically, Annex 13 defines an investigation as "a process for the purpose of accident prevention, which includes the gathering and analysis of information, the drawing of conclusions, including the determination of causes, and when appropriate, the making of safety recommendations (International Civil Aviation Organization, October 11, 1994)." Annex 13 also defines the rights and responsibilities of states involved in an accident investigation with regard to the notification, investigation, and reporting.

When an international aviation accident occurs, the NTSB appoints an accredited team of U.S. representatives to the investigation and supervises advisors from the U.S. aviation industry, including those from the FAA. The NTSB provides an objective and impartial representative to assist the authorities charged with managing an investigation outside the United States.

The interest the United States has in an international investigation and its need for involvement in the investigation stem from its obligations outlined in Annex 13 and its obligations under other ICAO requirements. The reasons for this interest and need are obvious with accidents involving U.S. registered aircraft and U.S. air carriers. In such cases, the NTSB provides direct assistance to those states conducting the investigation. Depending on the sophistication of its own investigative capabilities, the state where the accident occurred can delegate all or part of its responsibilities to the NTSB.

In addition, NTSB involvement enables U.S. authorities to take necessary accident prevention measures based on the findings of the investigation. However, U.S. interests are less clear in accidents involving non-U.S. airlines operating aircraft manufactured in the United States, or accidents involving non-U.S. airlines operating foreign manufactured aircraft that contain U.S. manufactured components.

The NTSB supplies other types of support to investigations conducted outside the United States. For example, the NTSB offers to provide readouts of CVRs or FDRs and metallurgical analyses of failed parts for other authorities involved in an investigation. The NTSB offers its assistance in accordance with the provisions of Annex 13 in a multitude of other forms, such as providing computerized information about accidents and incidents, or overseeing component testing or teardowns at U.S. manufacturing facilities. The NTSB's responsibilities under ICAO represent a significant, and growing, portion of the agency's total workload (this is discussed further in Chapter 5).

NTSB OPERATIONAL BASELINE

To understand the NTSB's mission and operations, RAND performed an in-depth statistical review using available financial and technical data. This baselining activity was designed to lay the foundation for later qualitative and quantitative analyses. These analyses include RAND researchers' exploration of the numerous issues that influence the party process and their assessment of the Safety Board's ability to meet future technical challenges.

The baselining effort was limited in many areas by a lack of data, and considerable effort was required to build alternative strategies for extracting trend information. RAND sought to the greatest extent possible to capture the entire NTSB history since its inception in 1968. This analysis required extensive integration of disparate information bases.

One should keep in mind that this study of the NTSB investigative process focused primarily on one mode of transportation: aviation.⁹ Other transportation modes received limited analysis. Although many of the trends in air travel described in this and subsequent chapters of this report are similar to trends found in other modes of transportation, RAND believes that extrapolating these findings is likely to generate error.

Operating Budget

Figure 2.1 depicts NTSB budget appropriations for the fiscal years 1980 through 1999, shown in inflation-adjusted dollars. The figure also shows NTSB staffing levels. The NTSB's current beginning-of-year funding is close to \$60 million. However, this initial appropriation does not necessarily represent the total funds available to the Safety Board in any given year. The NTSB can seek supplemental funding when situations require extraordinary investigative efforts or when simultaneous accidents cause an unplanned surge in workload (supplemental funding is not reflected in Figure 2.1).¹⁰

The availability of supplemental funding reveals a very important factor in NTSB operations. Access to supplemental funding provides the NTSB with a financial "surge capability" that enables it to conduct large or multiple investigations. However, the NTSB has no such surge

⁹RAND performed a survey of the NTSB's technical staff. At the request of the NTSB senior staff, and with the cooperation of all office heads, this survey was conducted for all transportation modes. This was done to facilitate later study and analysis by the NTSB.

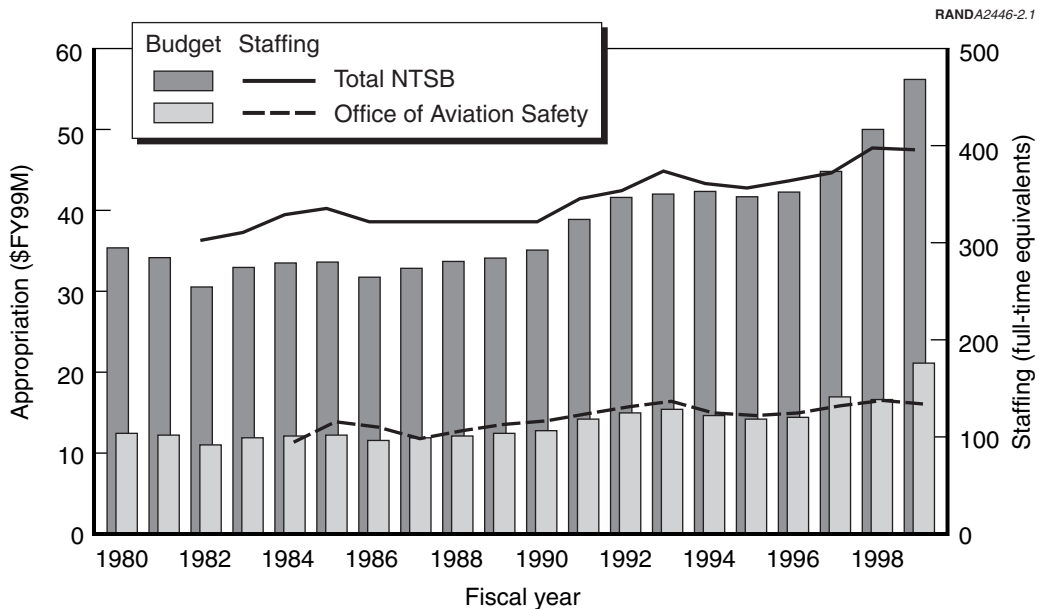
¹⁰In the past, budget supplements have generally been less than \$1 million, but lately they have grown dramatically. In 1997, for example, two supplements were required, mostly to cover the costs of the TWA Flight 800 investigation, which required extensive salvaging and reconstruction, and the USAir 427 accident. The 1997 supplements totaled \$38 million, nearly doubling the NTSB's budget.

capability for staffing. For example, unlike the Department of Defense (DOD) and some other government agencies, the NTSB has not established relationships with technical and engineering support services contractors that could augment the NTSB's workforce in times of heavy workload.

As Chapter 6 discusses, the NTSB maintains few strategic alliances with other federal agencies or with accident investigation agencies in other countries that could assist the NTSB when workload suddenly grows. Because of the stochastic nature of aviation accidents, the Safety Board's only option when several accidents occur in quick succession is to overload staff and stretch work schedules for a period of time.

Another important observation related to spending is the relatively large slice of the fiscal pie dedicated for aviation investigations compared with the portions allocated for investigation efforts for other transportation modes. The NTSB oversees events occurring in rail, highway, marine, and pipeline and hazardous material transportation, in addition to aviation. Yet, as shown in Figure 2.1, the OAS consumes nearly 40 percent of Safety Board's fiscal resources. This skew in spending is largely due to the high visibility aviation accidents have in the media and among the general public and the impact of air safety on the performance of the aviation sector of the economy. It is also surprising to note that field and regional offices consume approximately 50 percent of the fiscal resources dedicated to aviation.¹¹ The majority of this allocation goes to the investigation of small-aircraft accidents. Although the Safety Board is known primarily for investigating major commercial aircraft accidents, responding to events that occur in the GA community consumes an equivalent portion of internal resources and attention.

¹¹The investigation of GA accidents is almost exclusively assigned to the field and regional offices. While these offices are not exclusively dedicated to GA, the majority of the resources provided to field and regional offices are directed to the investigation of small-aircraft accidents.



NOTE: The figure shows initial annual appropriations. On several occasions, supplemental appropriations have been sought to cover extraordinary expenses. For example, the NTSB sought and was awarded supplemental appropriations for the investigation of TWA Flight 800 in the amount of approximately \$38 million, almost doubling the NTSB's FY 1997 budget.

Figure 2.1--NTSB Operating Budget and Staffing

Staff Overview

As shown in Figure 2.1, the NTSB staff consists of nearly 400 full-time equivalents (FTEs).¹² The majority of the staff is dedicated to technical investigations, either directly or in a supporting role. The staff of OAS constitutes approximately one-third of the total, or 130 FTEs. A significant percentage of the ORE staff, however, supports aviation investigations, some of them exclusively. In total, therefore, aviation accident investigations consume about 50 percent of the Safety Board's FTE allocation.

Figure 2.2 depicts the split between the headquarters staff and field and regional office staff for OAS. Currently, 86 field investigators are devoted to aviation accident investigations, mostly

¹²Data on NTSB staffing levels were gathered from internal NTSB personnel records and staff overviews produced at regular intervals in response to inquiries from the House Appropriations Committee, Subcommittee on Transportation.

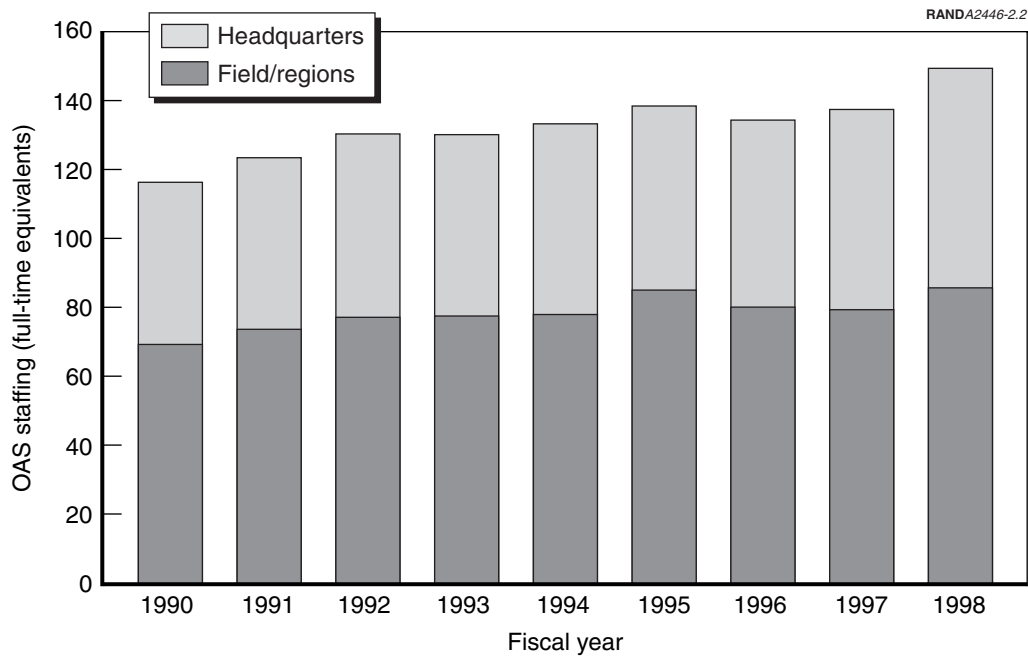


Figure 2.2--OAS Staff Distribution by Location

centered on Parts 91 and 135 unscheduled investigations.¹³ The OAS staff principally consists of accident investigators and technical support professionals, as shown in Figure 2.3.

Accident History

To understand the NTSB's workload and the magnitude of the investigative challenge, RAND needed to gain a historical picture of the

¹³The Federal Aviation Regulations (FARs) classify aircraft operation by type. The following four FAR parts pertain to aviation activities relevant to this report:

- Part 91--primarily GA aircraft, but also including business aircraft and rotorcraft, and experimental aircraft
- Part 121--domestic and flag-carrying transport category aircraft
- Part 129--foreign air carriers and operators of U.S.-registered transport category aircraft
- Part 135--commuter aircraft and air taxi services, and cargo operations

Parts 121, 129, and 135 are also broken down by regularly scheduled service and by unscheduled service. A 1996 change to the FARs reclassified scheduled commuter aircraft with more than 20 seats, and all jet-powered commuter aircraft, from Part 135 to Part 121 operations, thereby subjecting them to stricter safety and operating standards.

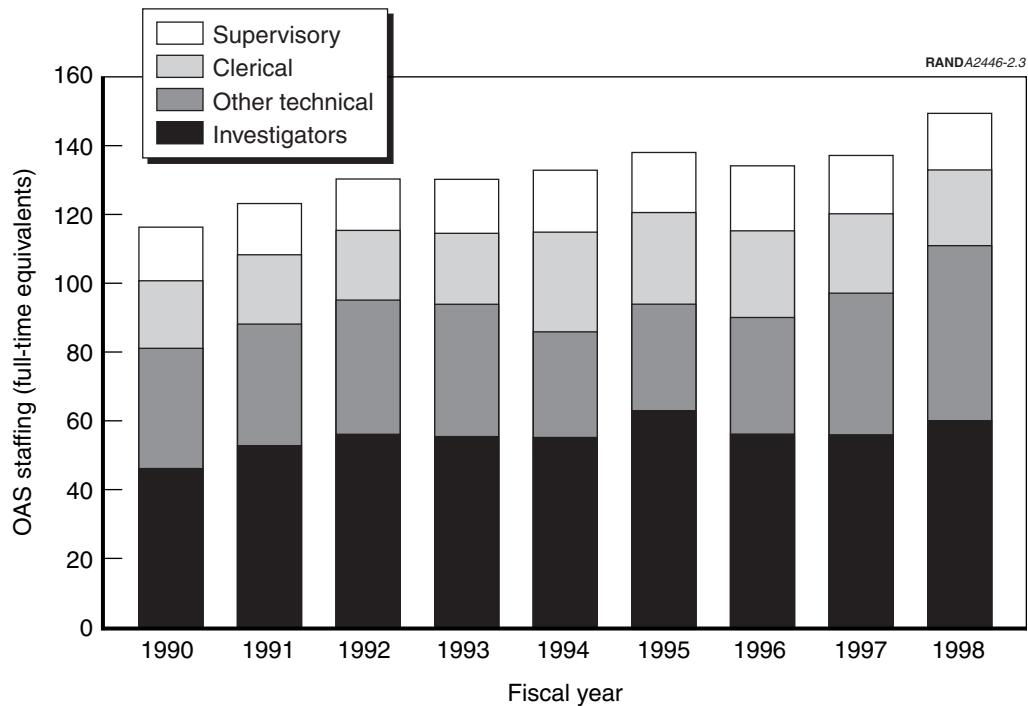


Figure 2.3--OAS Staff Distribution by Type

aviation accident rate. The NTSB maintains computer databases of the accident and incident investigations it performs. These are used primarily for archival purposes and not for historical analysis. RAND integrated several disparate NTSB data systems in order to build an analytical foundation for the study of accident rates and how the NTSB responds to them.¹⁴

RAND acquired information from the NTSB related to accidents in all areas of civil aviation. A 30-year view of the integrated NTSB accident record is shown in Figure 2.4. Typically, a discussion of aviation accidents deals with the relative safety of flying as the passenger demand for air travel increases. The number of accidents per flight hour, the number of fatalities per passenger mile, or some other similar rate measures the number of accidents against the demands placed on the air transportation system. In Figure 2.4, accident data are not

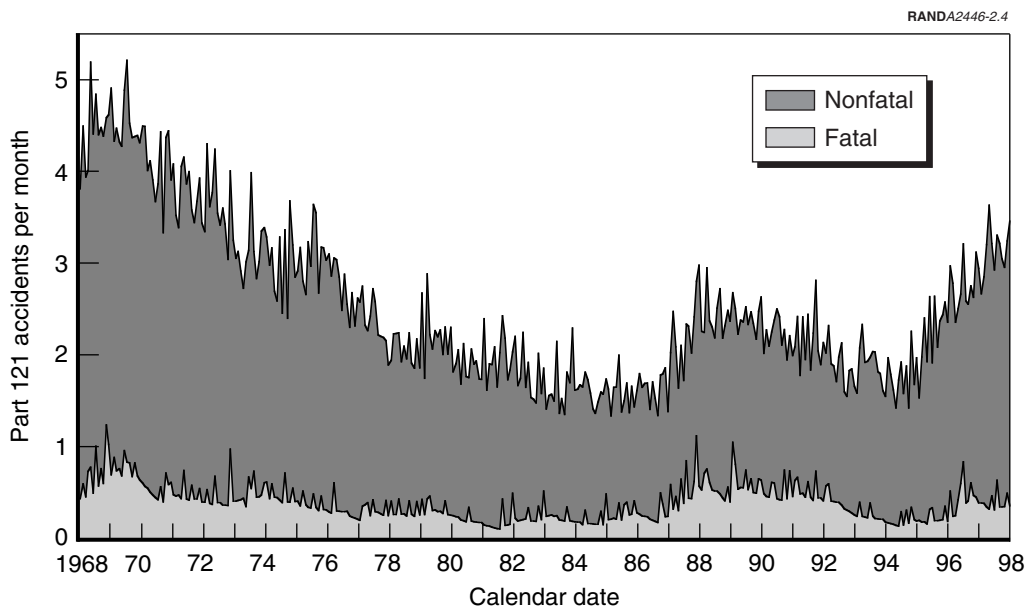
¹⁴This integration was especially complex in that NTSB records are kept on different computer platforms. Many data anomalies were encountered that required additional analysis. A summary of the extent and limitations of the resulting data set can be found in Appendix B of this report.

normalized in this way. Instead, Figure 2.4 shows a six-month moving average (the current month and the five previous months' accident data) of the number of aviation accidents per month.

By ignoring the steady growth in demand for air travel, Figure 2.4 does not reflect the improvements in air safety over the years. However, the figure does provide some insight into the scale and nature of the NTSB's workload. Regardless of whether the aviation industry's safety record is improving, the NTSB must maintain sufficient resources to investigate the actual *number* of accidents that occur each month.

Figure 2.4 also highlights two points that are important to NTSB staffing and workload:

- First, while the number of nonfatal accidents has declined dramatically since the late 1960s, the nonfatal accident rate is now on the rise. While *major* accidents involving domestic transport aircraft are certainly the most labor intensive to investigate, nonfatal accidents nevertheless consume significant staff time. The number of nonfatal accidents per month nearly doubled between 1986 and 1998.



NOTE: The data presented are a six-month moving average extracted from the NTSB's accident database for commercial transport aircraft operating under Federal Aviation Regulations Part 121.

Figure 2.4--Thirty-Year Accident History

- Second, the number of fatal accidents per month has not changed significantly over the 30 years of analyzed data. While safety has improved dramatically, the NTSB still has nearly the same workload, as measured by the number of fatal accidents. Additionally, the NTSB's staffing profile is fixed, at least in the short term; therefore, while the number of accidents can vary greatly, available staff remains the same. RAND examined closely the ability of NTSB management practices to balance workload and accomplish ongoing training and professional development in this stochastic environment.

An additional challenge that investigators face lies hidden within the aviation accident statistics: the growing complexity associated with crashes. The limited data record prevented a rigorous examination of factors associated with crash complexity, but RAND was able to establish a first-order *severity index* to establish a trend line. This index was formed by multiplying the size of the aircraft by a qualitative damage index that was consistently reported in the NTSB data record. The results are shown in Figure 2.5 for Part 121 and Part 129 accidents

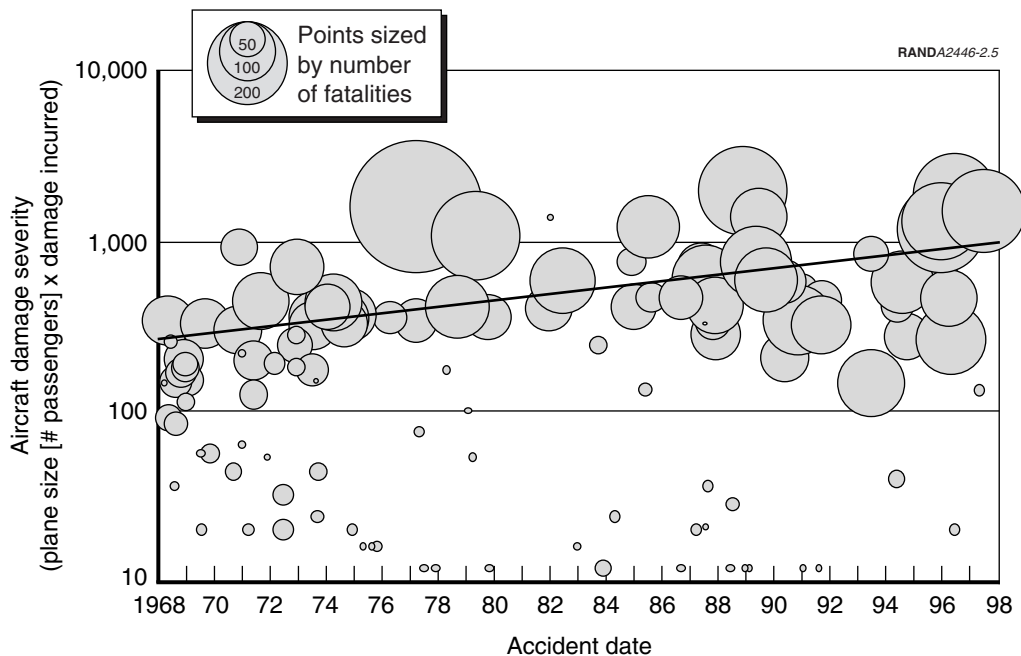


Figure 2.5--Growing Complexity of Transport-Category Aircraft

between 1968 and 1998. This semilog plot shows steady growth in the severity of accidents with which the NTSB must contend.

The complexity of a subsequent investigation is partly linked to the severity of the accident. The more extensive the wreckage, the more complex the job of attempting to isolate and characterize possible causal factors. Victim identification is also more complex. In severe accidents, reconstruction is becoming a more important investigational theme. Locating adequate facilities, building the requisite fixtures, and completing salvage operations take longer and require a more complex management process. The severity of the crash does not, however, get at the issue of system complexity associated with the accident. RAND believes that growing system complexity will be an additional factor that will heavily influence future NTSB accident investigation procedures.

The data record of aviation accident investigations contains both the accident date and the date of the report. From this information, RAND was able to approximate accident investigation time lines.¹⁵ Figure 2.6 depicts the average length of investigations from 1968 through 1998 for Parts 121, 129, and 135 fatal and nonfatal aviation accidents (excluding GA Part 91). The Part 121 average investigation duration is called out separately.¹⁶ The standard deviation, a measure of how consistently the NTSB concludes its investigations, typically increases at times when the average length of an investigation increases.

Throughout the 1990s, the NTSB frequently missed its one-year goal for completion of major investigations. The trend line in recent years is again climbing and, considering current NTSB workloads, it is likely that the 1999 average will remain high. Both an increase in the number of nonfatal accidents and the rising complexity of major fatal accidents are likely to be strong determinants of this trend.

¹⁵Although the precise report date may not always exactly correlate with the completion of the investigation, it is the best available approximation.

¹⁶Note that a gap exists in the database for the period 1983 to 1986. This and other anomalies in the data are described in Appendix B of this report.

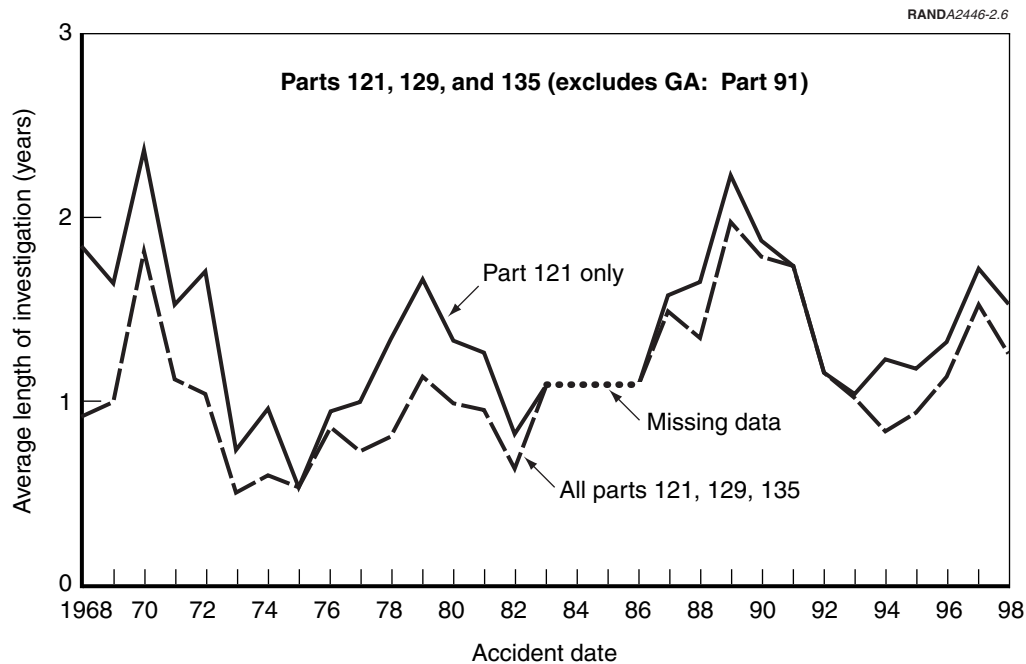


Figure 2.6--Accident Investigation Duration

While the NTSB's goal is the thorough analysis of accidents, in practice it must balance the need for additional investigation and research against its limited resources and the need for a timely resolution. A timely response is needed to ensure ongoing flight safety and to resolve the causal uncertainty associated with the deaths of many individuals.

As Figure 2.6 shows, although its responsiveness is highly variable, the NTSB has struggled to complete investigations in approximately one year. To achieve this goal, the NTSB must make tradeoffs. Safety Board managers face a great challenge in balancing resources across many open investigations. In monitoring its responsiveness, the NTSB ultimately must be the judge of the level of analysis required to determine *probable* cause. No equation exists for calculating probability when reaching a probable cause determination; the decision is subjective and not constant.

Interviews with NTSB managers and staff reveal an agency deeply committed to doing everything possible to resolving the cause of accidents in a timely fashion. However, as future chapters of this report describe, this level of commitment is strained by staff work

overload and insufficient attention to training. These problems are amplified by a lack of certain information that would help managers better balance the workload at all levels of the NTSB organization.

CHAPTER 3
EMERGING AVIATION TRENDS:
POTENTIAL IMPACT ON AIRCRAFT ACCIDENT INVESTIGATIONS

The nature of NTSB investigations and the agency's future workload will be shaped by changes in the aviation environment, in particular by increasing technological complexity and growth in general and commercial aviation air traffic, and by important changes in the composition of the air transport fleet. The burgeoning popularity of personal use aircraft will also impact the NTSB's workload.

This chapter examines these trends and how the Safety Board's processes are likely to be challenged by technological innovations that are changing both aircraft and the airspace in which they operate. Cumulatively, these technological changes aim to increase reliability throughout the aviation system and vastly improve safety in the skies. These changes include systems designed to move aircraft more efficiently in the air and on the ground, methods for providing pilots and ground controllers with better information about traffic and weather conditions, and improvements in aircraft components and design.

The growth in aircraft system complexity is exponential in many areas, with the most significant trend being the interconnectedness of systems. Current-generation aircraft operate as highly integrated systems with extensive cross-linking. As system complexity grows, so does the concern about hidden design flaws or possible equipment defects.

Accidents involving complex systems and events present investigators with new and different failure modes that multiply the number of potential scenarios they must consider. The historically common causes of accidents are occurring less frequently, leaving more challenging accidents to diagnose. In response, the NTSB must develop new investigative processes and training procedures to meet the challenges that the rapid growth in systems complexity presents.

IMPROVING THE SAFETY AND EFFICIENCY OF AVIATION

The dramatic loss of TWA Flight 800 in 1996 galvanized national concern over aviation safety and gave birth to the WHCASS. A 1997 report from the commission set a *national* goal to reduce the air carrier fatal accident rate by 80 percent within 10 years (Office of the President of the United States, January 1997). NASA also embraced this goal, but set an even more ambitious target--providing the technology to reduce the U.S. accident rate by 90 percent within 20 years (National Aeronautics and Space Administration, 1999). Boeing maintains a corporate goal of working with the aviation community to try to achieve a *worldwide* 50 percent reduction in fatal accidents over the next 10 years (Higgins, June 1998).

A three-agency alliance of the FAA, NASA, and the DOD are engaged in a broadly based joint research and technology development effort to meet the goals stated here.¹ Together, the three agencies are committing more than \$3 billion over the next five years to achieve the aviation safety and security goals. NASA alone has pledged to augment its existing aviation safety program budget by \$500 million during this period. Federal investment will likely continue at current levels beyond 2002 as the national airspace infrastructure continues to improve and as highly advanced technologies reach maturity and are implemented. These monetary investments have been made with three goals in mind:

- **Reduce accident precursors:** reexamining aircraft systems, ground equipment, operating systems, and procedures to reduce incidents that are known to precede fatal accidents. A significant reduction in the number of precursors should cause a parallel reduction in the likelihood of fatal accidents.

¹The role of the DOD in contributing to improvements in civil aviation safety is often underestimated. The DOD is the largest operator of aircraft in the world. The combined military services operate a total of 16,300 aircraft. As an air traffic control provider, the DOD and its facilities handled 11 percent of all nationwide air traffic in 1995. This amounted to 18.4 million aircraft, of which 3.7 million were civilian and 14.7 million were military. This experience base, as well as the many research and development initiatives under way to improve military aviation safety, profoundly influences the planning and implementation of civil aviation system improvements.

- **Create inherently safer aviation systems:** focusing on safety in the design of aircraft and aviation systems and the procedures used to operate them. This requires an understanding of how and why accidents occur, including a continuous reinforcement of lessons that have been learned.
- **Design failure-tolerant aircraft:** building systems that can withstand failures or that can maintain a safe environment for aircraft passengers and crew when a failure occurs.

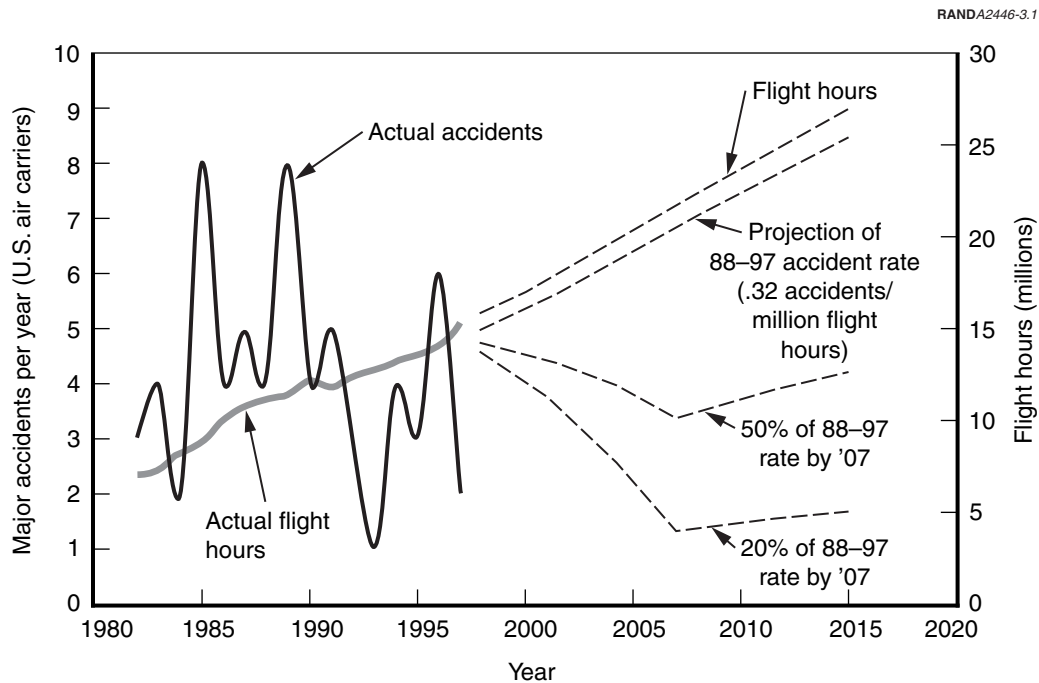
National Aviation Safety Goals

The future demand for NTSB's accident investigation services will be shaped in large part by the success of worldwide efforts to reduce accident rates. Impressive reductions in accident rates have been achieved since the first introduction of jet transports; however, that progress, measured in terms of hull losses per million departures, has tapered off during the last two decades.² Simply combining the current global accident rate with traffic growth projections leads to the oft-cited observation that if accident rates are not reduced within about the next 20 years a fatal air carrier accident could occur an average of once a week somewhere in the world (Office of the President of the United States, January 1997). This projection has motivated public and private sectors to develop initiatives to reduce accident rates.

Figure 3.1 shows the range of possible scenarios the NTSB faces in terms of potential domestic major accidents. The projections on the chart illustrate three projected accident trends:

- No change in accident rate (accidents grow in line with traffic growth)
- A 50 percent reduction in the accident rate by 2007
- An 80 percent reduction (20 percent of the 1988-1997 accident rate) by 2007, the Clinton administration's goal.

²An aircraft accident can be minor or major. A major event does not necessarily cause fatalities. Readers should note that although aviation safety goals target reductions in the fatal accident rates, the NTSB workload is determined by the number of minor and major accidents, not just those accidents that incur fatalities.



SOURCE: Developed from the NTSB Aviation Accident Data Base; FAA Long-range Aviation Forecasts, Fiscal Years 2010, 2015 and 2020, FAA Office of Aviation Policy and Plans, June 1998; FAA Aviation Forecasts Fiscal Years 1997-2008, FAA, March 1997; WHCASS and Boeing Safety Goals.

Figure 3.1--Projected Accident Rate Scenarios

The potential trends range from an appreciable drop to a significant increase in the number of accidents. If the first projected scenario (accidents grow in line with flight hours) becomes a reality, average accidents per year could double within the next 20 years, in all likelihood requiring an increase in NTSB staff.³ If the accident rate is halved, such as in the second scenario, that reduction will be almost completely offset by the effects of increased traffic, leaving the average number of accidents per year at today's levels. If the third scenario occurs, the accident rate will fall faster than the projected traffic growth, potentially resulting in a net decline in annual U.S. air carrier accidents.

At this point, three years into a 10-year program, it is far too early to consider making staffing adjustments based on an expectation of

³The projections assume a linear transition from the current accident rate to the new accident rate by 2007, although actual accidents would never be expected to occur in such monotonic fashion.

fewer U.S. air carrier accidents in the future. Moreover, focused research and development that leads to a reduction in the number of domestic accidents, however positive, is offset by two important realities:

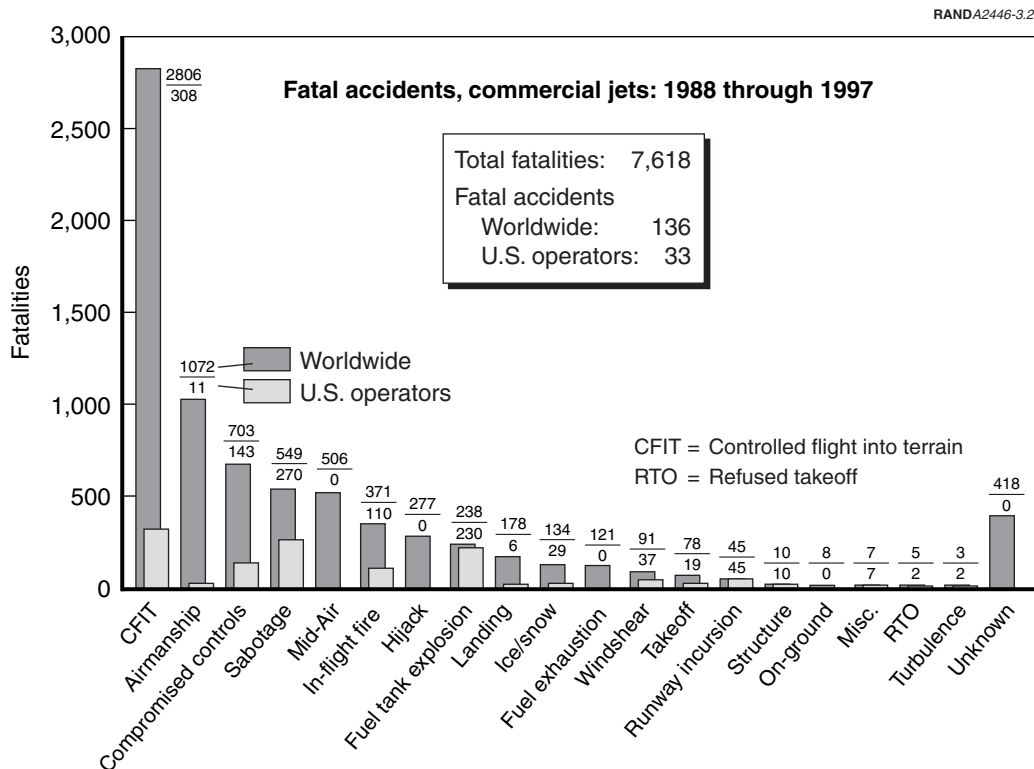
- First, the nature of aircraft crashes will likely change and the NTSB will face a substantial increase in the complexity of accidents and the level of interest surrounding investigations, particularly in terms of litigation and the intensity of public scrutiny.
- Second, the level of NTSB support to foreign investigations depends on the effectiveness of international safety initiatives. Whereas the U.S. and Canadian accident rate for hull losses and/or fatal accidents is roughly one loss per one million departures, the rate in the rest of the world is three times higher (Boeing Commercial Airplane Company, June 1998, p. 13). Even when a U.S. carrier is not directly involved in an accident, NTSB frequently has an interest in its outcome because such accidents can have implications for operators of similar aircraft. As a consequence, the future demand for NTSB's accident investigation services will be significantly affected by the success of worldwide--and not just domestic--efforts to reduce accident rates.

Figure 3.1 underscores the point that there is no clear future trend for accident rates. The NTSB must maintain a flexible long-term strategy for dealing with accidents, emphasizing its ability to leverage external resources to deal with the historic variability in accident numbers. It is apparent that the NTSB must strike a balance between bearing the expense of staffing for peak demand periods, and staffing for somewhat lower demand levels and accepting that a certain amount of overtime is inevitable.⁴

⁴Such variability in accident occurrences also makes it more difficult to identify progress in accident reduction efforts with any certainty.

The Safety Research Agenda

Ongoing safety efforts have aimed for maximum effectiveness in reducing accident rates by focusing on the most common accident causes. As shown in Figure 3.2, the three most frequent causes of accident fatalities are controlled flight into terrain (CFIT), airmanship, and loss of control.⁵ Note the disparity in CFIT fatalities for U.S. operators and operators worldwide. New ground proximity warning equipment, superior training, advanced air traffic control equipment, and improved operating procedures make CFIT a much less frequent occurrence for U.S. operators than for operators in the rest of the world.



SOURCE: Boeing Commercial Airplane Company, June 1998.

Figure 3.2--Fatalities and Fatal Accident Numbers by Cause of Crash

⁵A CFIT event occurs when "a mechanically normally functioning airplane is inadvertently flown into the ground, water, or an obstacle." See Flight Safety Foundation, 1997, for a complete description of CFIT events and the steps being taken to prevent them.

Safety initiatives in the United States are already eliminating many of the most common causes of aircraft accidents. Consequently, the accidents that the NTSB may be called upon to investigate in the future could be much harder to diagnose. Investigating the crash of USAir Flight 427, which involved complex analysis of rudder design and pilot behavior, is one such example. Over time, the NTSB may see a reduction in the number of fatal accidents it investigates, but it may not experience a commensurate reduction in workload as accident investigations grow in complexity.

Accelerated Introduction of New Safety Technology

The greatest challenge in aviation today is being able to meet the need for increased capacity while simultaneously reducing the potential for an accident. Over the next 15 years, the NAS and the aircraft that fly within it will integrate technologies aimed at meeting this goal.

It will be critically important for the NTSB to keep abreast of these modernization initiatives as they are phased in. There may, in fact, be opportunities for the NTSB to shape the evolution of the system to better facilitate future accident investigations.⁶ Many of the new technologies will introduce enhanced cockpit systems that increase the level of automation and dependence upon computer-based systems. Other changes will result from an extensive overhaul of the NAS architecture, including fundamental shifts in aircraft control, weather prediction, and communications.

Motivated by congestion, economics, and safety concerns, NAS modernization plans will touch on virtually every phase of aircraft operations, materially changing equipment, operational procedures, and the means by which NTSB captures information for diagnosing what happens in an accident.

⁶The implementation schedule for the National Airspace Architecture is divided into three phases: Phase 1 (1998-2002), Phase 2 (2003-2007), and Phase 3 (2008-2015). Phase 1 includes upgrades to controller computer workstations, deployment of satellite-based navigation systems, and air-to-air surveillance. Beyond Phase 1, the architecture is still evolving (Federal Aviation Administration, January 1999).

Most research into increased capacity focuses on three key areas:

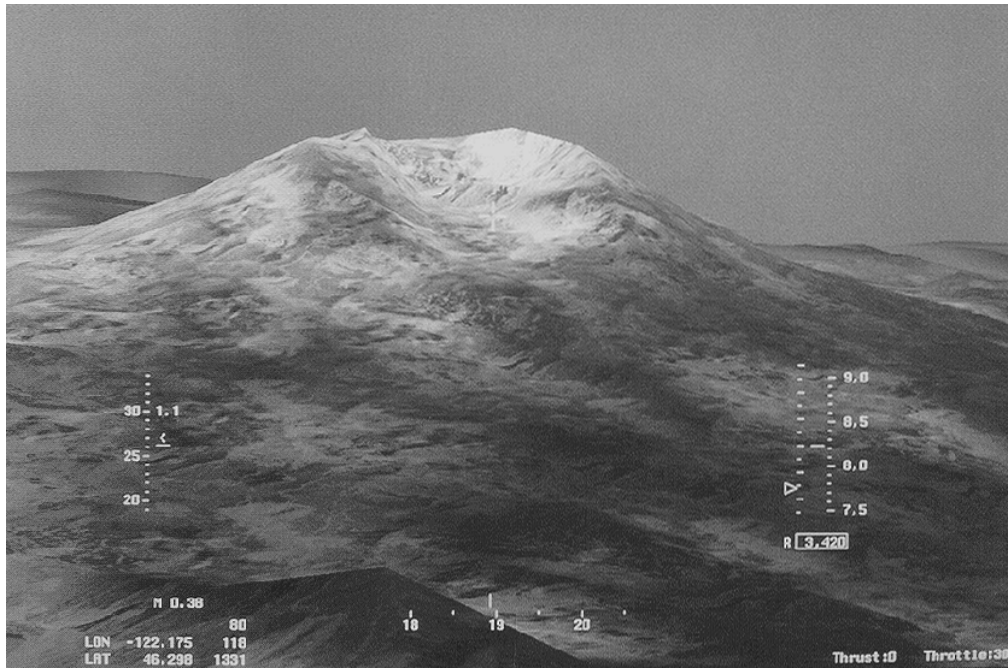
- improving the ability to fly in all weather and with higher densities of air traffic
- using airspace more efficiently
- processing aircraft through and around terminal areas more quickly.

Weather has long posed a threat to aviation safety. Perhaps the greatest threat stems from the pilot's reduced visibility. Many CFIT accidents are weather related. In the future, pilots will be able to use advanced technology to "see through the weather." This ability, combined with methods for predicting clear-air turbulence and other weather phenomena, will give operating crews and ground controllers a comprehensive map of what lies ahead.

Advanced weather monitoring systems integrate GPS systems for precision navigation with detailed computer-generated topographic maps, providing a view that is very similar to a flight view under visual meteorological conditions. This form of "synthetic vision," a sample of which is shown in Figure 3.3, is just one example of the emerging technologies aimed at reducing CFIT accidents.

Satellite-based precision navigation will also improve the ability of aircraft to accomplish all-weather landings. The FAA will approve Category I precision approaches using GPS-based technologies by 2001. Category II/III precision approaches will follow as augmentations to satellite-based navigation signals are deployed. The success of these improvements depends largely on the accuracy of weather forecasting information. However, the need for improved weather data has not yet adequately been addressed in the NAS architecture (Lindsey, December 31, 1998, p. 2-1). Improved accuracy and longer-range predictive models are essential to a more efficient NAS of the future.

The second of the key research areas listed earlier--more efficient utilization of airspace--relies on integrated communications, navigation, and surveillance (CNS) systems. Improved cockpit communications will advance the concept of a more self-reliant pilot, reducing air traffic controller workload and voice traffic congestion. Digital aircraft communication systems will increasingly rely on



SOURCE: Lewis, June 1998.

Figure 3.3--Synthetic Vision Display Prototype

satellite communications. Advanced CNS technologies will require a greater ability to account for all aircraft within a given location to ensure that flight path conflicts do not occur.

This advanced CNS is the foundation on which the concept of "free flight" is based. The FAA, NASA, and DOD are cooperating on the development of Automatic Dependent Surveillance systems with a broadcast capability (ADS-B). ADS-B systems will derive aircraft positions using GPS technology that locates aircraft with extreme precision. Aircraft identity, altitude, and position information will be integrated and digitally broadcast to ground receivers and the pilots of nearby aircraft. This precise location information will enable aircraft to operate at speeds and altitudes optimally suited to a flight.

Oceanic air travel is expected to grow by more than 30 percent over the next five years. To handle this expansion, the FAA is developing the Advanced Oceanic Automation System (AOAS), which aims to make oceanic flight more like free flight. To accomplish this, U.S. and overseas controllers, as well as en-route aircraft, must be able to share information and select flight profiles that accommodate higher

traffic densities. With AOAS in place, pilots will be able to fly more fuel-efficient routes, taking advantage of aloft winds and using more efficient weather-avoidance procedures.

The third principal R&D initiative--improved airport and terminal operations--will create new cockpit and terminal displays that increase throughput and reduce delays.⁷ Delays and congestion are often related to inclement weather. As air traffic increases, the ability to schedule arrivals and departures to achieve the smoothest possible traffic flow becomes increasingly important. The FAA and NASA are working together on improving air operations in the vicinity of airports. As a leading operator of aircraft in the nation, the DOD is drawing on its experience base of high-density air operations to contribute technical expertise to the effort.

NASA, under its Terminal Area Productivity program, is developing an array of advisory tools to permit higher densities of air traffic. For example, the Traffic Management Advisor (TMA) provides advanced graphical displays and alerts for air traffic controllers. The system generates statistics and reports about traffic flow and estimates the arrival time for each aircraft entering controlled airspace. TMA also recommends a runway assignment to optimize the traffic flow.

A Descent Advisor (DA) provides advisories that ensure fuel-efficient and conflict-free descents with arrival times accurate to within 10 to 20 seconds. NASA's Passive Final Approach Spacing Tool (P-FAST) is another decision support tool for air traffic controllers. P-FAST allows controllers to manage landing sequences and runway assignments to properly space the flow of traffic on final approach.

Other NASA initiatives aim to shorten the current separation requirements for landing aircraft in order to increase throughput. The Aircraft Vortex Spacing System provides precise separation measurements to prevent a landing aircraft from touching down before the wing-tip vortices from the preceding aircraft have safely dissipated. The system

⁷The FAA reports that 23 of the nation's busiest airports are currently experiencing more than 20,000 hours of delays each year. Delays costs airline operators an estimated \$3 billion annually and the congestion creates potential safety hazards (Federal Aviation Administration, June 1998).

uses sensors to measure the vortex and adjusts the separation requirements appropriately.

The Airborne Information for Lateral Spacing (AILS) system monitors the distance between aircraft approaching parallel runways using ground-based differential GPS devices. AILS will allow aircraft to safely operate in closer proximity as they approach parallel runways.

These efforts to land aircraft more efficiently will help to increase throughput. Nevertheless, simultaneous improvements in the flow of aircraft after landing are needed to prevent congestion on taxiways and ramp areas. NASA is pioneering a system called Taxi Navigation and Situational Awareness (T-NASA) which could significantly speed up aircraft movement to and from terminal gates. T-NASA will relay taxi instructions to the pilot's computer and provide a moving image of the aircraft and other traffic in proximity to it. The system will allow pilots to safely taxi at higher speeds, even at night and during periods of low visibility.

A related system called Roll Out and Turn Off, which displays information to the pilot to optimize braking distance, will help to shorten an aircraft's time on the runway. Ground controllers must also be able to monitor the location and movement of aircraft moving to and from gates. The FAA and NASA are jointly developing a Surface Movement Advisor, which integrates airline schedules, gate information, flight plans, radar data, and runway configurations to help ground controllers better control the movements of arriving and departing aircraft.

Other new systems are designed to prevent conflicts in low-visibility conditions. An example of this technology is NASA's Dynamic Runway Occupancy Measurement (DROM) system. By predicting the time it will take for a given type of aircraft to land and clear a runway and then passing this information to other flight planning systems, DROM determines the spacing of landing aircraft, which ensures that runways are clear of conflicting traffic.

This proliferation of advanced technology designed to meet the pressing demands of increased safety and performance may also introduce new safety threats into the commercial aviation equation. Increased reliance on satellite-based navigation, for example, carries with it

some measure of risk. The most significant threat to safety--intentional jamming of GPS signals during critical phases of flight--poses a significant hazard (Corrigan et al., 1999, p. 5-6; Federal Aviation Administration, October 1998, p. 18).

Systems that migrate into the cockpit will likely increase pilot workload. With the emergence of new computer-screen "glass-cockpits," complaints from pilots regarding work levels are on the rise. These workload problems are heightened when ground controllers make last-minute changes to flight profiles or fail to fully appreciate the performance characteristics of new aircraft.

A recent study conducted by the Australian Bureau of Air Safety Investigation (BASI) found that nearly 60 percent of surveyed pilots think that ground controllers do not fully understand the capabilities of the aircraft the pilots operate (Bureau of Air Safety Investigation, June 1998, p. 22). More than 60 percent of the pilots surveyed reported that automated systems generated actions they did not anticipate (Bureau of Air Safety Investigation, 1998, p. 32). Nevertheless, pilots appear ready and eager to accept and work with the new technology. Only 10 percent of pilots thought that too much automation had crept into the cockpit and 70 percent expressed confidence that crew management aboard advanced technology aircraft posed no problem (Bureau of Air Safety Investigation, June 1998, pp. 30, 35). These results correlate with similar studies conducted in the United States (Federal Aviation Administration, June 1996; Wiener, June 1989).

The systems described here are directed toward transport category aircraft; fewer efforts are underway to integrate GA aircraft with new operating concepts. The large numbers of small aircraft operating in the new NAS will require affordable avionics. GA operators have little or no ability to recoup the cost of new equipment. Therefore, integration of advanced technology into the GA fleet tends to happen slowly and the impact of R&D initiatives for increased safety will be less immediate in the GA fleet.

Federal R&D programs are attempting to bridge the gap between transport and GA aircraft technology through joint initiatives with the avionics industry. For example, developing low-cost avionics is an

objective of NASA's Advanced General Aviation Transport Experiments program, but commercial availability is several years away. Furthermore, funding cuts for aeronautics research have limited the program's scope (Warwick, May 1998, p. 6). Ensuring that air transport and GA aircraft can safely operate together in the new NAS will require careful planning.

In addition to becoming familiar with how a new system operates, NTSB investigators will need to learn where information resides in the system and how to extract it after an accident or incident. For instance, datalink messages may eventually replace voice communication records, and GPS-based position reports from individual airplanes may eventually replace centralized radar tracking records. While the new NAS could ultimately provide a richer collection of information to be used for accident diagnosis, its operation will require an enhanced skill set. The NTSB will encounter significant training challenges over the next two decades as the system evolves and is deployed.

GROWING COMPLEXITY IN AVIATION: IMPLICATIONS FOR THE NTSB

To overcome limitations in performance or reliability, most "inventors" deliver solutions that merely build additional complexities onto existing structures. Every once in a while an inventor comes along who does just the opposite, and solves a problem by making a complex system simple. A good example is Frank Whittle and his invention of the turbojet engine. It came at a time when aircraft piston engines had become layered with complex systems such as turbo-superchargers and power recovery turbines designed to extract every ounce of available horsepower. As might be expected, the jet engine of today is itself a study in complexity that bears only a vestigial resemblance to Whittle's original.

Increasing complexity is a natural phenomenon and one familiar to the NTSB. Nevertheless, the implications of growing complexity in aviation will likely have a profound impact on future NTSB operations. Future aircraft will be far more reliable, but the challenges associated with tracing the circumstances of their failures will require new ways of doing business. The following sections examine some of the factors

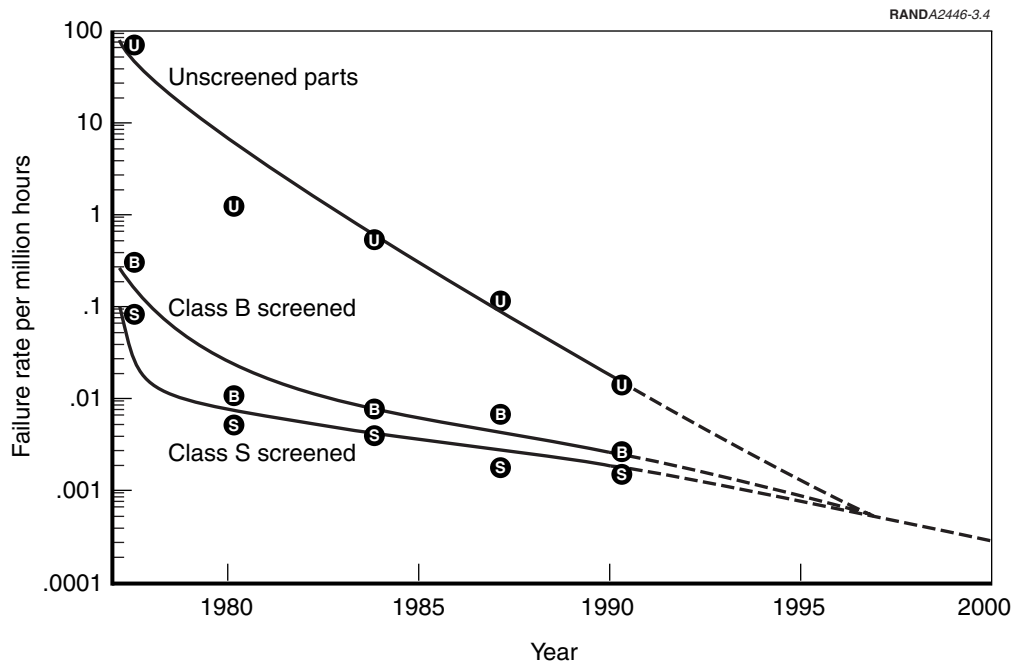
the NTSB must examine as it enters the age of extraordinarily complex systems.

Increasing Reliability of Aircraft and Ground Systems

Dramatic improvements in flight safety are largely made possible by increasingly reliable aircraft. Improvements in the reliability of aircraft systems can be traced to four primary sources:

- **High Reliability (Hi-Rel) parts and components.** The performance of both mechanical and electrical devices continues to improve. Electronic parts improvements have been especially dramatic. As Figure 3.4 shows, high-grade commercial electronic parts (unscreened parts) are now as reliable as military-grade equipment (Class B and Class S screened parts). NASA and Air Force Hi-Rel R&D programs are significantly improving component performance in aerospace applications.⁸
- **Improved test techniques.** Underlying the drive for improved quality and reliability is a shift from empirical explanations for failure mechanisms to a more scientific approach. The *physics-of-failure* method, for example, applies reliability models, built from exhaustive failure analysis and analytical modeling, to environments in which empirical models have long been the rule.
- **New system design approaches.** Improved design techniques are being employed to reduce the risk of errors. Integrated product teams (IPTs) are credited with facilitating communication among design teams, thereby reducing preproduction problems. Better control of technical requirements has helped streamline the development process and further reduce errors. In addition, collaborative techniques such as the Computer-Aided Three-Dimensional Interactive Approach (CATIA) and simulation-based design enable engineers to catch design errors early in the development cycle.

⁸The Air Force Reliability Analysis Center at Rome Air Force Base monitors Air Force initiatives related to high reliability. At NASA, programs are coordinated out of the Office of Safety and Mission Assurance in Washington, D.C.



SOURCE: Plum, 1990.

NOTE: Class B and Class S parts refer to military-grade components; Class S parts are rated for spaceflight.

Figure 3.4--Decline of Electronic Parts Failure Rates

- **Increased emphasis on product assurance.** In the past, individuals charged with the product assurance function served primarily as "assurance police." Today, product assurance is more often integrated into the design effort, providing up-front quality management.

Advancements in the performance and reliability of aircraft systems should lead to steady improvements in safety. However, increasing complexity will continue to challenge the ability of engineers to eliminate design errors before new aircraft and systems are fielded.

Design-Related Accidents: A Growing Danger

The first fatal crash of a powered aircraft was traced to a design-related failure (Crouch, June 1990). As aviation science yielded increasingly sophisticated design tools, other failure modes became the dominant cause of aircraft accidents. Paradoxically, although the overall aviation system will likely experience continuous improvements in safety, and therefore lower accident rates, a greater percentage of

incidents and accidents in the future will likely be traced to design problems. This is primarily because design-related events are not likely to decrease as quickly as events related to other causes of accidents and incidents.

The causes of failure can be sorted into five categories: environmental factors, failure of systems and electronic parts, quality defects, operator error, and design-related problems.⁹ (A generic "unknown" category is also used for cases in which cause cannot be established.) Table 3.1 presents a qualitative assessment showing that design-related problems are likely to rise proportionately to the following trends:

- **Crashes caused by environmental factors are decreasing.** A great deal of research has focused on reducing the number of accidents caused by environmental factors. Wind shear accidents, for example, have been largely eliminated in recent years. CFIT accidents are also on the decline. Like other accidents that trigger safety improvements, the 1974 CFIT loss of an airliner approaching Washington's Dulles airport prompted the FAA to mandate the use of Ground Proximity Warning Systems (GPWS). In the United States, the accident rate for domestic airline accidents attributed to CFIT dropped from an average of eight aircraft per year to one aircraft every five years following the implementation of the new GPWS technology (Bateman, November 1994, p. 2). As in the case of wind shear accidents, the drop in the rate of accidents attributable to CFIT can be traced to many factors: new on-board and air traffic control systems (such as GPWS and the implementation of Minimum Safe Altitude Warning Systems in tower radar), improved training programs, and educational programs for pilots and controllers.¹⁰
- **Relatively few accidents are caused by on-board system failures.** Current data from Boeing indicate that only about 10 percent of

⁹This categorization is taken from military and civil databases used to track failures in aerospace systems.

¹⁰While the rate of CFIT accidents and incidents has been substantially reduced, further reductions in the rate have proven difficult to achieve (Menzel, April 1998).

accidents are caused by aircraft systems failures (Boeing Commercial Airplane Company, June 1998, p. 21). A 1971 analysis of aircraft avionics failures traced 50 percent of system failures to problems with parts. Less than 20 years later, a similar study conducted in 1990 found parts failures to be negligible (Pecht et al., December 1992, p. 1161). System reliability improvements will continue to significantly reduce these types of failures.

- **Operator error is often rooted in design problems.** Pilot error constitutes by far the largest proportion of the accident and incident cause record, cited in an estimated 55 to 75 percent of accidents and incidents. However, the tendency to cite "operator error" is being reexamined, as it can mask more complex interrelated causes (Greenfield, November 1998a, p. 15). Experts are beginning to suspect that the human-machine interface is the true source of many operator errors. For instance, pilot uncertainty over computer modes in the cockpit continues to be a potential source of safety problems (Phillips, January 30, 1995, p. 63). Future investigations are likely to implicate design problems as either the probable or contributing cause of accidents that would have previously been attributed to pilot error.

Advanced design tools, new methods of organizing design teams, and increased collaboration among designers have helped manufacturers improve the performance and reliability of aerospace systems. Research has also been conducted to validate design algorithms. For example, studies have attempted to correlate accident and incident statistics with design parameters, such as lift and stability characteristics or power and wing loading. Generally, this research has concluded that the design practices in use today produce robust safety margins.¹¹

¹¹One study has suggested that a correlation exists between directional stability and accident tendencies in commuter aircraft (Smith and Gerhardt, August 11, 1993). Also, some alarming incident and accident trends are prompting a careful consideration of some design selections. The decision to forgo leading edge slats on some regional

Table 3.1
Projected Changes in the Cause of Failures

Failure factors	Failure trend	Technical forces driving trend	Percentage of cause
Environment	↓	<ul style="list-style-type: none"> • T/ADWR, LIDAR systems • GOES-Next, space-based surveillance upgrades • Synthetic vision and “through the weather” HUDs • Improved ice detection/removal systems 	↓
Design	↓	<ul style="list-style-type: none"> • Integrated product design, product design centers • CAE, CATIA • Simulation-based design 	↑
Parts	↓	<ul style="list-style-type: none"> • Hi-Rel parts and components • “Pick and Place” machines, surface mount manufacturing • MEMs, MCMs, Ultra-PEMs • CARMA 	↓
Quality	↓	<ul style="list-style-type: none"> • Physics-of-failure strategies • Improved testing/screening techniques • Embedded PA 	↓
Operational	↓	<ul style="list-style-type: none"> • Improved flight/maintenance/operations simulation • TCAS II, EGPWS, IDACS, next generation CNS • GPS precision nav, ADS-B, AOAS • Reclassification of human factors–type accidents 	↓
Unknown	↓	<ul style="list-style-type: none"> • Fault tolerance/isolation systems • Improved failsafe and error detection techniques • Increase in FDR parameters 	—

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Although engineering practices continue to improve aircraft design and introduce increasing levels of safety, they will likely be outpaced by the reduction of failures from environmental factors or problems with on-board systems. The greater scrutiny being paid to operator-related events is also likely to reduce operator error as a primary source of failure. The net result of these trends is that a growing proportion of aviation accidents will be traced to design-related failures.¹²

jet aircraft, for example, has led to concern over the operation of aircraft without leading edge slats in icing conditions.

¹²Previous RAND research noted a similar trend of a growing proportion of design-related failures in the satellite industry (Sarsfield, 1998, p. 119).

A rise in the proportion of design-related events will require the NTSB to make changes in the way it conducts accident and incident investigations:

- First, because design failures can have fleetwide implications, parties to an accident are likely to be more guarded during investigations. The Safety Board should anticipate having to expend more resources in such circumstances.
- Second, design-related failures are likely to involve more testing, research, analysis, and simulation to uncover hidden failure modes.

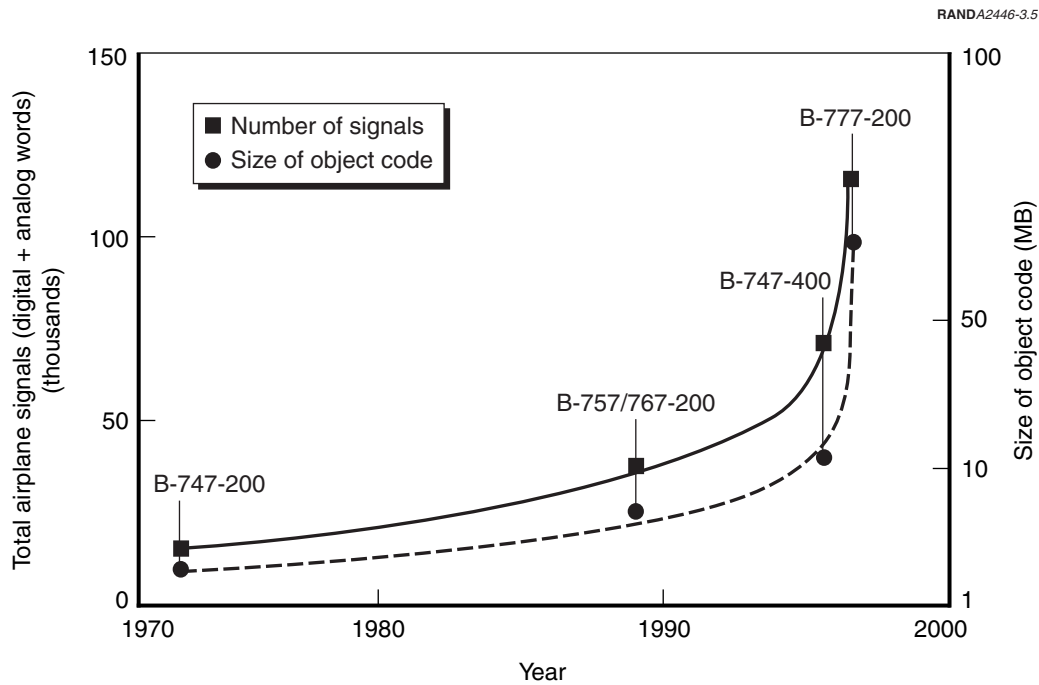
For both these reasons, the NTSB will need to improve its relationships with external organizations and rely more heavily on outside expertise.

In summary, while declining accident rates may imply a decrease in the NTSB's workload, it is more likely its workload will actually increase. When dealing with design failures, the NTSB's investigations will demand a greater amount of research and a shift in staff skills and experience (see Chapter 5 for further discussion). The Safety Board will need to develop new alliances to tap a knowledge base it cannot afford to maintain on its own.

Additionally, the NTSB will need better analytical tools, along with new ways to simulate the performance of designs in action. Design errors can be found in any system, but because glitches are often due to a failure to anticipate certain interactions among the system components, or between the system and its environment, they will occur more frequently as the number and complexity of system behaviors and interaction grows. This is the subject of the next section of this chapter.

NTSB Will Need New Investigative Methods

The increasingly complex electrical and mechanical systems that operate aircraft have long challenged accident investigators. Figure 3.5 illustrates two examples of growing complexity--the increase in signal architecture (digital and analog) and installed software (megabytes of code) in Boeing aircraft. Here the growth is exponential. These trends,



SOURCE: Weener, 1997.

Figure 3.5--Increasing Complexity in On-Board Software

however, tell only part of the story. The growing complexity of individual systems is compounded by the increasing interconnectedness of systems. In the past, aircraft operated with single-point, sensor-to-instrument systems. Current-generation aircraft, by comparison, operate with highly integrated systems with extensive cross-linking.

Complex systems are often highly interactive and tightly coupled; failures in one area can propagate rapidly to other areas. Some analysts have concluded that accidents involving complex systems are inevitable and have coined the term "normal accidents" to describe them.¹³ In aviation, however, accidents do not appear to be "normal." Engineers understand a great deal about the operation of complex systems and have reduced coupling by using robust designs that contain built-in fault isolation and redundancy. These design improvements allow modern aircraft to operate with both unprecedented complexity and reliability.

¹³The earliest use of this term was by Charles Perrow in his seminal text *Normal Accidents* (Perrow, 1999).

It is interesting to note that many cases of failures in complex systems can be traced to the failure of safety systems themselves (Langewiesche, March 1998, p. 98).

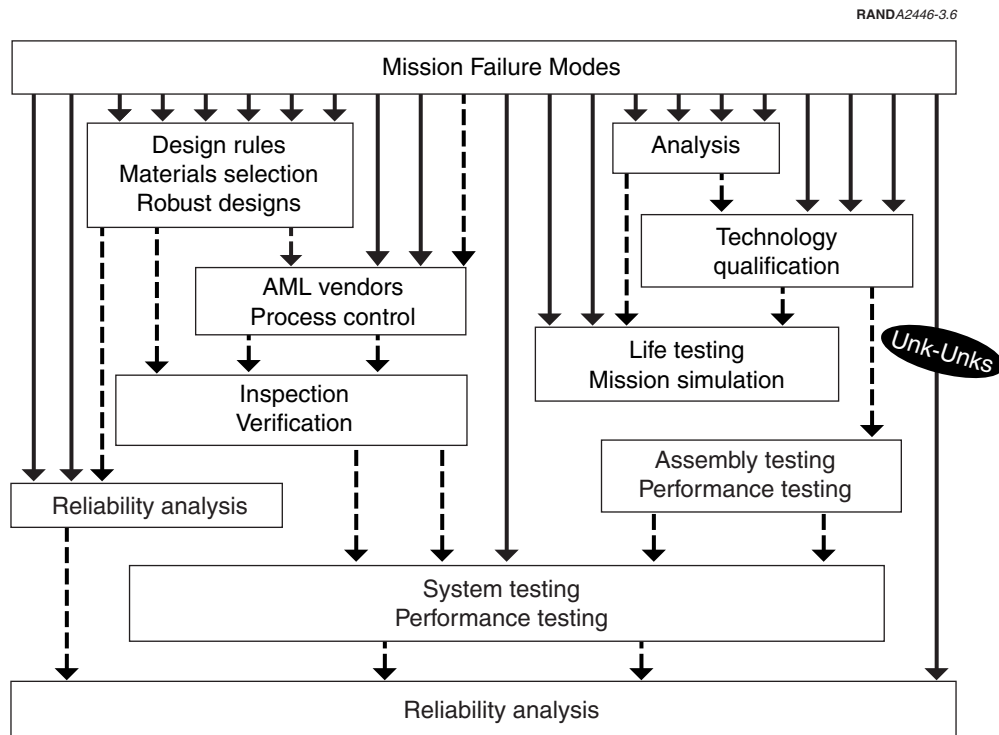
Although systems are becoming safer, their growing complexity raises concerns that should be addressed by the NTSB. The potential for problems is especially acute in relation to human-machine interactions, as noted by a former NTSB manager:

I doubt that any manufacturers' aircraft are completely free of potential for human error incidents and/or accidents; i.e., they have in their design, . . . pathogenic bugs that will only become manifest under the "right" set of conditions, sometimes with only embarrassing consequences, and sometimes with tragic ones (Lauber, September 19, 1994).

Most notably, manufacturers may be less able to predict the many failure modes inherent in a complex design. Figure 3.6 is a high-level depiction of the stepwise methods used to eliminate defects and potential failure modes from engineering designs. The right side of the figure includes a mode for so-called unknown-unknowns ("unk-unks") that engineers have not considered and that existing tests are unable to eliminate.

Extensive research continues on new quantitative methods for identifying design defects or production errors, but a gap still exists in the ability to assess the expected reliability of highly complex systems. This is especially true in the area of computer software. Increasingly, aircraft functions rely upon software. Aircraft manufacturers are faced with the task of improving performance and reliability while remaining cost competitive. Higher levels of integration, largely enabled by a growing reliance on software, allow engineers to accomplish these tasks.

Electronic systems are also replacing many mechanical components. This is most notable in flight control systems (fly-by-wire) but also in other areas such as digital fuel control units and fully electronic navigation systems. Higher levels of integration and greater use of electronic components demand increased software requirements. Software is, by its nature, a malleable product that is likely to receive



SOURCE: Cornford, 1996, p. 4.

NOTES: 1) Each box represents a collection of Preventions, Analyses, Controls, and Tests (PACTs).
2) Dotted lines represent "escapes"—undetected/unprevented failure modes.

Figure 3.6--Defect Propagation Model

extensive modification, expansion, and re-engineering prior to integration into a larger system. It is reasonable to expect, therefore, that errors and faults in overall systems increasingly will be traced to software.

Detecting faults in software is notoriously difficult. The implications of even minor code errors were graphically demonstrated by the loss of an Ariane 5 launch vehicle on June 4, 1996. The investigation revealed the cause of the accident to be a design error in the vehicle's inertial reference system software (European Space Agency, July 19, 1996). More recently, the Air Force lost a Milstar spacecraft because of an inaccurate software load that apparently went undetected during the validation process (Covault, May 10, 1999, p. 28).

Typically, software engineers must rely on testing, diversity in design, and fault tolerance to remove errors or reduce their impact. For ultra-reliable, safety-critical applications, testing using statistical

risk quantification or classical methods is not feasible because an extraordinarily long test time is needed to achieve high levels of assurance (Butler et al., January 1993, p. 7). The use of parallel design teams to develop independent software solutions for a given set of requirements has also been shown to be unreliable (Holloway, October 1997, p. 9).

That leaves techniques that seek to avoid faults as the most appropriate for safety-critical applications. Of these, so-called "formal methods"--the application of discrete mathematical proofing tools--have been found to be highly effective in safety-critical applications, such as aircraft flight control systems (National Aeronautics and Space Administration, July 1995b, p. 30). Formal methods employed during the specification and verification phases of software development help to reduce faults in software elements, but they cannot eliminate doubts about the overall performance of a system (Rushby, May 1993, p. 139). Formal methods can, however, help engineers understand the overall fault environment and create more fault-tolerant designs as a result.

Although the NTSB has long dealt with rising complexity, two factors will drive a fundamental re-ordering of investigative management and processes. The first is the large number of potential failure scenarios that need to be evaluated in a complex systems accident. The second is the impermanent nature of evidence associated with a complex systems event.

Only a limited number of crashes, even among the latest generation of aircraft, will likely be caused by a systems-related failure. When such events do occur, however, NTSB investigators should expect to rigorously explore a significant number of failure potentialities. During the investigation of a complex systems accident, the NTSB will probably face the following challenges:

- **Lack of failure mode data.** The manufacturer may not be able to provide ready information after an accident because the failure mode may not have been experienced before. In cases such as this, parties to the accident will be less able to respond quickly to information requests from the NTSB.

- **Exhaustion of resources.** Complex events multiply the number of potential failure scenarios. Limited NTSB resources could cause investigators to perform failure analyses serially instead of in parallel, greatly prolonging the analytical phase of the investigation.
- **Demands for specific expertise.** The ability to examine failure scenarios will require diverse yet highly focused technical skills that often are beyond the range of Safety Board personnel. Individuals managing the investigation will need to identify outside experts and enlist their support quickly, often outside of traditional party mechanisms.

NTSB investigators have already witnessed the extraordinary number of failure scenarios the crash of a modern aircraft can generate. In the USAir Flight 427 investigation, for example, the accident team dealt with a virtually endless number of possible scenarios (Harr, August 1996, p. 49). Such accidents will require the NTSB to develop new methods for running simultaneous analyses, prioritizing resources, and assessing the probability that any given scenario may be the right one.

The fact that complex events may fail to present clear reasons for equipment or system failures poses a considerable challenge to traditional Safety Board investigative practices. RAND found that NTSB investigators are well prepared for accidents in which the failure mode reveals itself through a careful examination of the wreckage. An appreciation for the fact that catastrophic failures can occur in complex systems without obvious physical evidence was less apparent. The "broken bolt" or "severed cable" represents the type of mechanical failure that can be located quickly by analyzing debris. This type of "permanent state" failure is readily identifiable. In complex systems, "reactive state" failures can occur (Gerdsmeier et al., June 1997, p. 1; Ladkin, June 1998). Such modes of failure do not persist and therefore evidence needed to trace the cause of failure is not available to investigators.

As complexity increases so does the need for enhanced observation of systems performance during a failure event. The ability to "observe" the performance of an aircraft is determined by the fidelity of the FDR.

New aircraft carry high-fidelity FDRs, and this will likely improve the ability of the NTSB to establish what happened during an accident. However, additional analysis will be necessary to determine whether high-fidelity FDRs will more quickly reveal the cause of failures in complex systems.

Increasingly complex systems underscore the importance of ongoing training. Operators of complex systems must reach a performance level that matches the capabilities of the system (Flight Safety Foundation, December 1994, p. 10). In a similar vein, accident investigators must be trained not just in investigative techniques but in a broad, multidisciplinary routine that reflects the complexity of the systems they will be called upon to analyze.

This type of long-term training program cannot be fully implemented with internal NTSB resources alone. The NTSB will need to develop cooperative relationships with aviation industry manufacturers and operators, university-based researchers, and other government agencies.

THE CHANGING COMPOSITION OF THE TRANSPORT FLEET

Air travel continues to increase in popularity. Significant growth is projected in both the number of passenger miles flown, domestically and overseas, and in the size of the fleet needed to meet the increasing demand. The NTSB must plan for a larger and more diverse fleet and for changes in the manufacturing base of suppliers.

The FAA projects that between 1997 and 2010, domestic flight hours will increase by 56 percent for air carriers, 81 percent for regional/commuter carriers, and 25 percent for general aviation (Federal Aviation Administration, June 1998). This is in line with forecasts of worldwide commercial air travel growing by roughly 5 percent per year for the next 10 years in the air carrier segment (Boeing Commercial Airplane Company, June 1998).

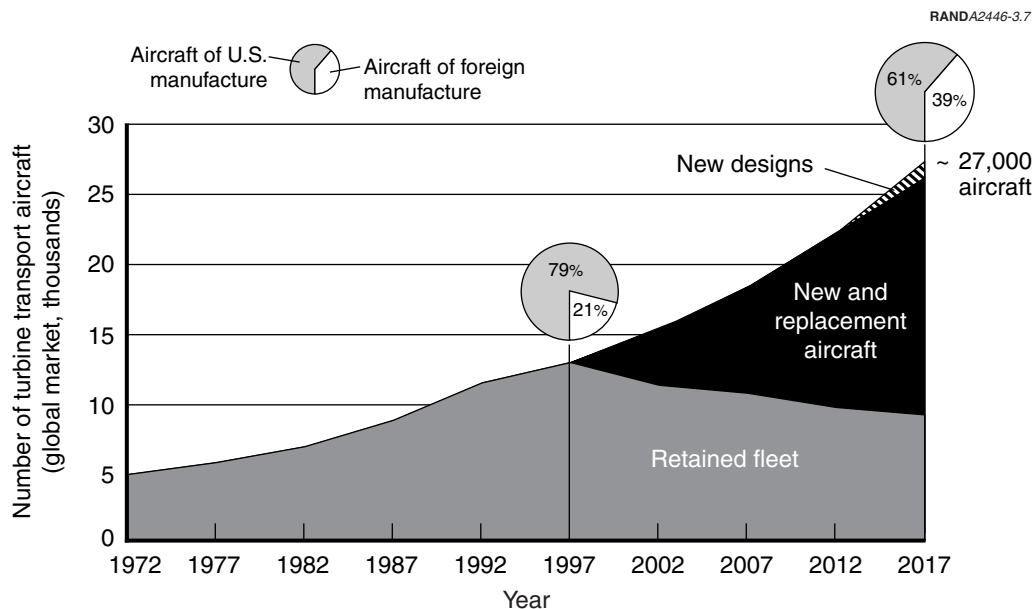
This growth in the air carrier segment is expected to double the number of aircraft in the worldwide air carrier fleet by 2015, as shown in Figure 3.7. The air carrier growth is accompanied by several parallel trends: aircraft types and systems will proliferate, the number of

foreign-built aircraft will increase, aircraft will carry more passengers, and the overall aircraft fleet could be older. These trends, which are discussed in the following sections, must be addressed by NTSB senior managers who are charged with keeping pace with change.

Diversity of Aircraft Types and Systems

Figure 3.7 shows that manufacturers see only a limited market for completely new aircraft designs. Airlines will purchase additional or replacement aircraft that are for the most part evolved from current designs. The fact that radically new aircraft designs (such as the supersonic transport) are not in the offering somewhat lessens the NTSB's responsibilities in regard to training or hiring.

Nevertheless, even serial improvements in current designs will present a challenge to aviation accident investigators. Significant design changes accompany each new aircraft series, particularly in the aircraft's onboard systems. Cumulatively, these system changes can produce designs that bear only a structural resemblance to the original aircraft. Additionally, operator-selected options and modifications



SOURCES: Boeing Commercial Airplane Company, June 1997; Airbus Industrie, April 1998.

Figure 3.7--Projected Future World Transport Fleet

produce tremendous diversity among aircraft within a fleet. After an accident, NTSB investigators will need to consult closely with both the manufacturer and the aircraft operator to fully understand how the aircraft is equipped and how it might have performed during an accident.

This diversity within a fleet poses a systems-level challenge to the NTSB. Training programs should be designed to focus on the most generic components of change. Identifying features that are common among aircraft whenever possible will allow the NTSB to better target its training programs.¹⁴ In addition, instruction on new technologies that underlie the development of new systems, such as GPS-based navigation techniques, should form a core element of any training program.

As the world transport fleet doubles in size over the next two decades, the percentage of aircraft built by non-U.S. manufacturers is also expected to nearly double, from 21 percent to 39 percent. During 1998, the number of Airbus Industrie orders came to within 100 of Boeing's aircraft orders, although deliveries by Airbus lagged by several hundred airplanes.¹⁵ Airbus Industrie's goal is to acquire a sustainable 50 percent share of the aviation market (Sparaco, October 5, 1998a, p. 5).

As U.S. and foreign carriers increase their use of foreign aircraft, NTSB investigators will have to become much more familiar with their design and operation. They must also be prepared to work with the foreign aviation community, including manufacturers, operators, regulators, and accident investigators.¹⁶

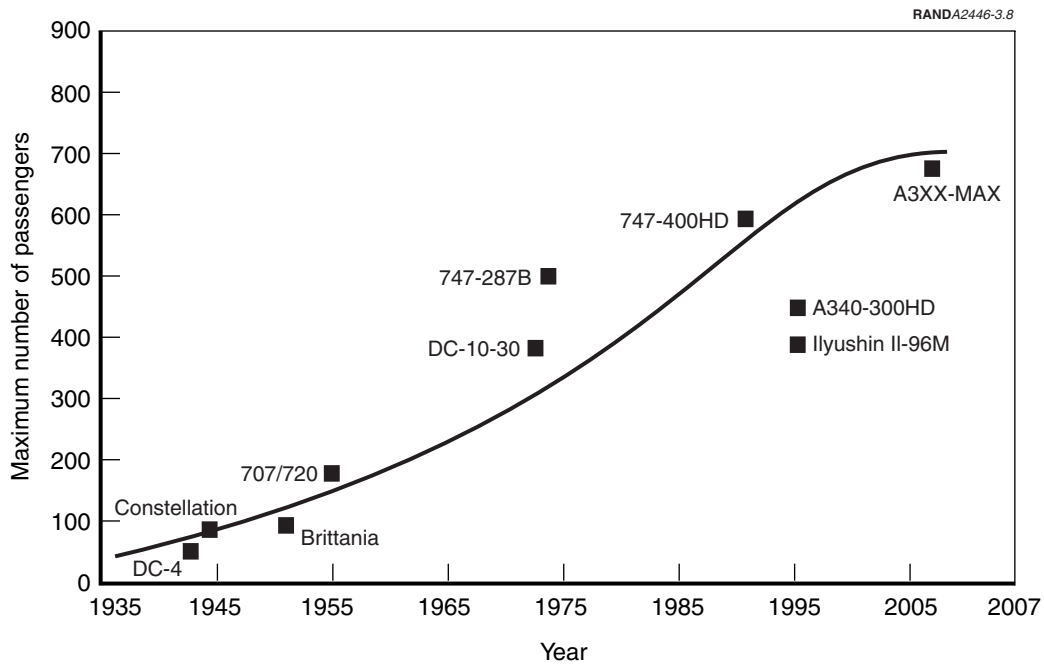
Larger Aircraft with Higher Passenger Densities

In the worst crash in aviation history, two Boeing 747s collided in 1977 in Tenerife, Canary Islands, killing 578 passengers and crew. As

¹⁴Cockpit procedures for the Boeing 757 and 767 are similar, for example. The Airbus series of transport aircraft have extensive cockpit commonality.

¹⁵Sales figures were developed directly from data available from the Boeing Commercial Airplane Company (www.boeing.com) and Airbus Industrie (www.airbus.com) Web sites.

¹⁶This is equally applicable to the regional/commuter aviation segment, in which the vast majority of the U.S. fleet is from foreign manufacturers.



SOURCE: *Jane's All the World Aircraft*, multiple years.

Figure 3.8--Growth in Passenger Capacity of Transport Aircraft

shown in Figure 3.8, aircraft passenger capacity has grown to the point that an event of the magnitude of the 1977 crash could involve just a single aircraft. Alarming, incidents have occurred that clearly demonstrate the potential for just such a disaster.¹⁷

Industry planners are now considering building very large transport airplanes capable of carrying up to 800 passengers. Such designs will strain safe aircraft operations. For example, although emergency evacuation of several hundred passengers (which currently must be done in under 90 seconds) has been demonstrated in certification tests, it is thought by many to be impossible during an actual emergency.

As aircraft design measurably improves, so does the public's expectation that even higher levels of safety will be achieved. A single

¹⁷In 1998, a United Airlines Boeing 747 with 307 people aboard narrowly missed a hill after experiencing an engine loss on takeoff from San Francisco International Airport (Carley, March 19, 1999). This, and similar close calls, could be harbingers of a domestic accident of unprecedented proportions.

event in which close to a thousand people are killed would certainly receive unprecedented media attention. An accident of such magnitude would also severely tax NTSB resources, leaving limited resources for other investigations. Furthermore, aircraft such as the Boeing 747-400 combine unprecedented passenger capacity with the latest-generation technology. Should a major fatal accident occur, and should it involve complex design-related issues, the event could consume virtually the entire Safety Board aviation staff.

Accidents resulting in a large number of fatalities focus increased public attention on the NTSB and its operations, creating a very challenging work environment. The average passenger capacity of commercial transport aircraft is projected to increase over the next two decades, although this could be tempered by the airlines' tendency to add capacity by increasing the number of flights rather than by flying bigger planes.¹⁸

Increasing the passenger capacity of regional/commuter aircraft that operate at high flight frequencies offers comparatively greater leverage in terms of reducing airport congestion. For this reason, the FAA projects a marked increase in the size of aircraft in future U.S. regional/commuter fleets.¹⁹

The Aging Fleet

In the past, airlines operated aircraft as long as possible, with the assurance from manufacturers that safe operation could be maintained provided inspections and maintenance were routinely performed. Boeing estimates that approximately 20 percent of all commercial jet airplanes flying today are considered to be "aging" airplanes (McGuire, April 1998, p. 4), meaning that they have exceeded their original design

¹⁸During the next 10 years, Boeing projects larger aircraft will account for an 8 percent growth in available seat miles, longer routes will account for a 3 percent growth, and increased flight frequencies for 89 percent of the growth. The 8 percent growth, while seemingly modest, still represents five times as much growth in available seat miles due to larger airplanes than occurred in the prior 10 years (Boeing Commercial Airplane Company, May 1998, p. 35).

¹⁹Between 1997 and 2009, the FAA projects the proportion of U.S. regional/commuter passenger aircraft having 20 or more seats to grow from 50 percent to 71 percent (Federal Aviation Administration, 1998a).

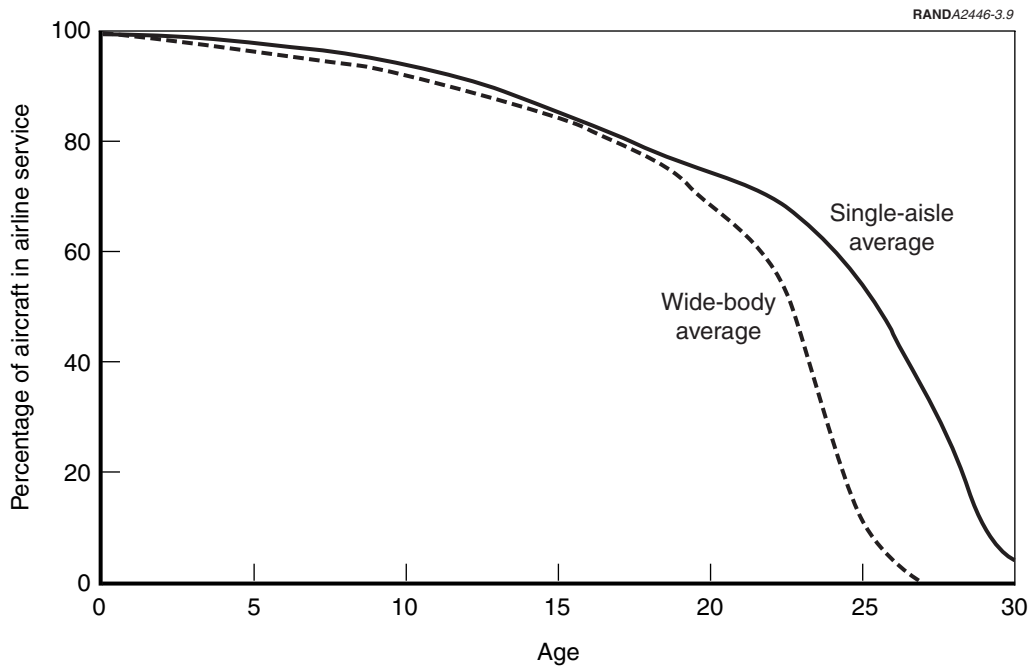
service objective (DSO). The DSO of U.S.-designed commercial airliners is 20 years.²⁰ Most of the first- and second-generation jet aircraft in the commercial fleet have exceeded this limit. The average Boeing 737-100, for example, is 29 years old, and GA fleet aircraft are estimated to be 28 years old on average (General Aviation Manufacturers Association, 1998, p. 11).

A reverse trend is emerging in the commercial aviation fleet. In the modern air travel marketplace, the need to maintain an up-to-date image, conform with noise abatement requirements, and hold down maintenance costs is making operators rethink their strategies on retiring aircraft.

As shown in Figure 3.9, airlines today do not expect to operate an aircraft for more than 30 years. Therefore, it is reasonable to assume that potential issues associated with the safe operation of aging aircraft will decline in the long-term because of the lower percentage of aging aircraft. However, the NTSB could face aging issues in the near term. Because aircraft retired from domestic service often enter service with foreign carriers, and because the NTSB increasingly is called upon to assist with international investigations, the NTSB's workload could increase if problems with aging foreign-owned aircraft develop. Whether or not age affects the safe operation of aircraft is clearly an issue that could influence NTSB planning.

It is unfortunate that research in regard to aging aircraft systems has lagged behind the airline industry's decisionmaking. Although the FAA and DOD are finalizing analytical methods that will quantify the risks related to operating aircraft beyond their design lives, some airlines have nevertheless elected to depend heavily on older aircraft.

²⁰It is important to remember that the DSO of an aircraft is a goal related only to an aircraft's primary structure, not to systems placed within the structure. The DSO essentially seeks to ensure that the airframe remains free of significant fatigue cracks during a 20-year period given expected utilization rates.



SOURCE: Airbus Industrie, *Global Market Forecast*, 1999.

Figure 3.9--Operator Strategies for Aging Aircraft

In the past, some carriers saw a cost advantage associated with forgoing the purchase of new aircraft and opting instead for renewal of older ones. In 1994, for example, Northwest Airlines chose to expand its fleet of older DC-9 aircraft and refurbish them to meet current standards. Although the decision saved the company the purchase price of new aircraft, substantial unplanned expenditures were required to ensure adequate maintenance. Published reports showed that the older fleet experienced unscheduled landings at a rate four times that of airlines operating similar but newer equipment, and that increased maintenance workloads required the airline to hire 1,200 additional mechanics (Carey and McCartney, June 12, 1998).

As an aircraft ages, growth in maintenance costs to keep the plane flight-worthy can be dramatic. How the aircraft is maintained, where it is operated, and how it is utilized throughout its life affect subsequent maintenance costs. Maintenance cost is also heavily

influenced by the initial DSO and engineering choices made by the manufacturer.²¹

The Air Force's experience with aging aircraft indicates that aircraft can be safely operated well beyond the original DSO. Several Air Force systems are now more than 30 years old. The B-52 bomber and KC-135 tanker are the most notable cases, but the C-141 transport and T-37 and T-38 trainers are also aging platforms (U.S. Air Force, October 1998a, Table E-16). The Air Force currently operates 76 B-52Hs with an airframe limit of 32,500 to 37,500 hours on the upper wing surface (U.S. Air Force, March 1999, p. 21).²² The Air Force plans to operate its B-52Hs until approximately 2040. At that point, the B-52H would be more than 80 years old.

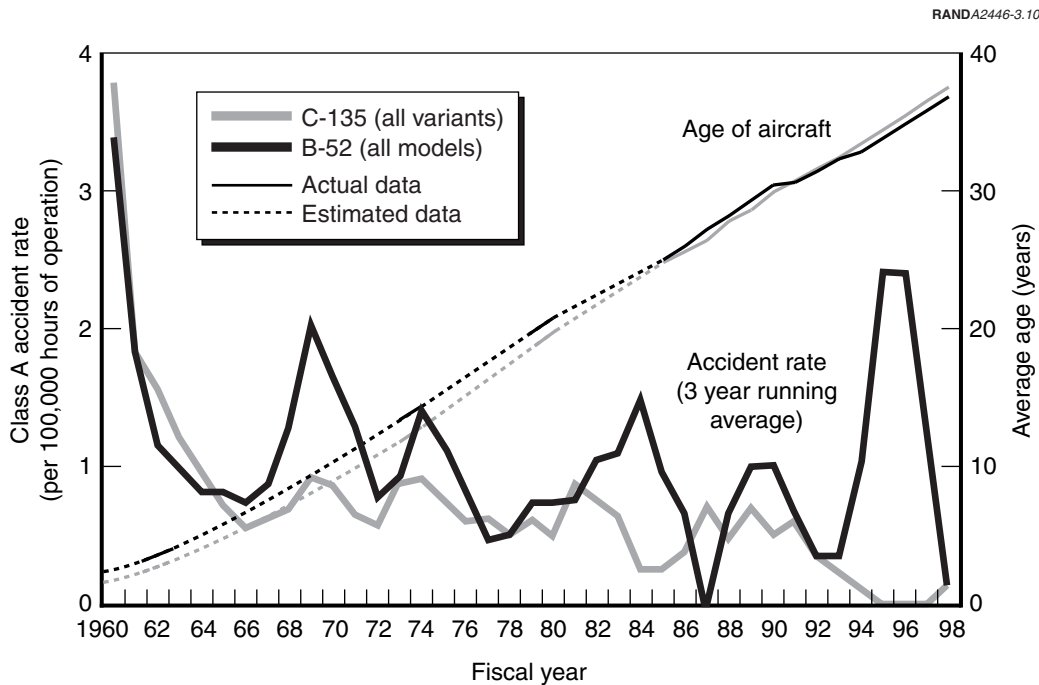
A RAND study found that the Air Force fleet, currently averaging 20 years old but projected to climb to 30 years old over the next two decades, will probably incur rapid growth of maintenance costs along with the risk of loss of availability (Pyles, 1999). Similarly, a 1997 National Research Council (NRC) report highlighted the problems associated with maintaining an older military fleet (National Research Council, 1997). The NRC concluded that the economic burden resulting from aircraft maintenance could quickly become so overwhelming, and the availability of aircraft so uncertain, that the fleet could become nonviable. However, the *safety* of the Air Force's fleet may not be affected.

Figure 3.10 shows the Air Force's lifetime safety experience with its aging B-52 and C-135 aircraft, as measured by the rate of Class A mishaps.²³ The trends shown in Figure 3.10 are consistent with a general trend of declining Class A mishap rates for Air Force aircraft (U.S. Air Force, October 1998b). Although the Air Force may experience loss of availability of aircraft, reduced operating limits, and higher

²¹A discussion of maintenance cost growth can be found in DiDonato, December 4, 1997.

²²Earlier B-52 variants were retired from service. The H model continues to be modified to meet changing mission requirements.

²³The definition of a Class A mishap has changed over time, but the term refers to a severe event, currently defined as damage in excess of \$1 million, or an event that results in a fatality.



SOURCE: Compiled from the *U.S. Air Force Statistical Digest*, various years, and data provided by the Air Force Safety Center's Mishap Prevention and Epidemiology Branch (HQ AFSC/SEPR).

NOTE: Includes regular Air Force, Reserve, and Air National Guard active aircraft; excludes acts of war.

Figure 3.10--Accident Rates for C-135 and B-52 Models by Age of Aircraft

operational costs with its older aircraft, Figure 3.10 indicates no unusual loss rate associated with older systems.

Extrapolating military experience to the commercial aviation fleet is not, however, a straightforward affair. Large military aircraft typically fly far fewer in-service hours in a given year with far fewer takeoff-and-landing cycles than the typical commercial transport, and with less predictable patterns of use.²⁴

Inspection and maintenance procedures on a military aircraft versus a commercial airliner are also quite different. The military's "inspect and repair as necessary" (IRAN) process is roughly equivalent to "D"

²⁴The average C-135, for example, operates approximately 350 hours per year. A commercial transport, by comparison, might fly eight times as many hours in a year.

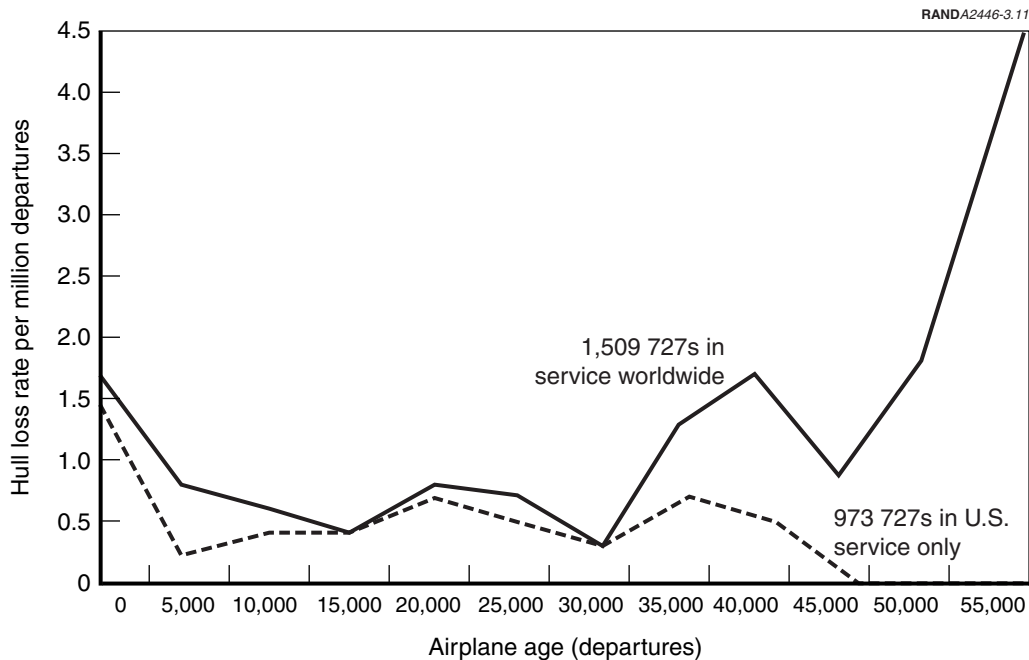
checks in the commercial fleet.²⁵ Although military overhaul and maintenance procedures have been curtailed in recent years, an aircraft completing an IRAN is, in many ways, restored to its delivery condition.²⁶ Air Force maintenance procedures are uniform, whereas considerable variation exists in airline maintenance procedures related to aging aircraft (DiDonato, December 4, 1997, p. 10).

To track the operation of individual aircraft, the Air Force also maintains a complex system designed specifically for evaluating maintenance requirements. This system, the Aircraft Structural Integrity Program (ASIP), closely monitors factors that affect the aging of an individual unit in the Air Force fleet (Giese, April 1998). The service history and flight profile of each aircraft are combined with information related to structural repairs on the airframe, inspection results, and maintenance history. The system compares analytical results against a baseline of structural and performance capabilities supplied by the aircraft manufacturer. The resulting quantitative foundation allows inspection and maintenance procedures to be tailored to individual aircraft.

Although maintenance procedures and the approach to dealing with aging systems in the military differ from those in the commercial world, available data indicate that aging has not yet become a significant safety problem in the airline industry. Figure 3.11 shows the hull loss accident rate for the popular Boeing 727 aircraft. For the venerable 727, the domestic accident rate has actually dropped to zero. The rising worldwide accident rates probably reflect the operation of these

²⁵Airline maintenance is allocated in a sequential series of checks, beginning with visual "A" checks at 100 hours, "B" checks at interim frequencies, "C" checks occurring approximately every 1,500 hours or annually, and "D" checks at 18,000 hours. Both "C" and "D" are considered heavy maintenance. The "D" check is a depot maintenance procedure that includes significant teardown of the aircraft, structural sampling for corrosion and cracking, detailed systems testing, and the replacement of worn components.

²⁶The IRAN process has been replaced by programmed depot maintenance (PDM). Earlier RAND research concluded that many of the repairs performed during PDM could be performed at the aircraft's base. Over time, Air Force PDM requirements have generally lengthened the PDM requirements for aircraft (Donaldson and Poggio, November 1974).



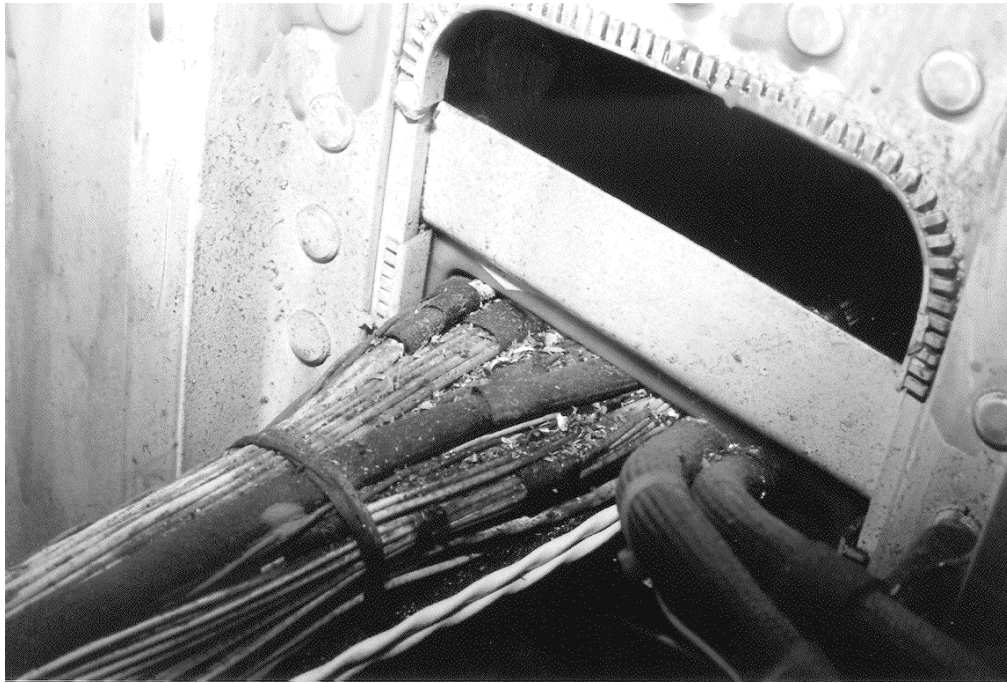
SOURCE: From Boeing Commercial Airplane Company, based on actuarial data from Airclaims, Ltd.

Figure 3.11--B-727 Hull Loss Rate by Aircraft Age

aircraft in environments with less rigorous maintenance procedures, fewer navigational aids, and flight crews with less training.

The 1988 accident of Aloha Airlines Flight 243 near Maui, Hawaii, focused attention on widespread fatigue damage (WFD) (National Transportation Safety Board, June 14, 1989). A growing body of evidence is now making clear that aging effects are not limited to WFD. The performance of engines, avionics, and other flight systems is also affected by age, a fact suggested by the TWA Flight 800 crash. The ongoing investigation has already caused a fundamental shift in thinking about the contributing factor that aging *systems* add to the operational equation. The issue of electrical wiring deterioration in older aircraft is a case in point. Bundles of electrical wires could potentially be exposed to chemical attack, chaffing, damage caused by maintenance and modification, and temperature extremes.²⁷

²⁷Repair, modification, and alteration of the airframe often involve drilling into aluminum sections. Falling debris in the form of metal chips has been found to cause significant damage to wiring bundles



SOURCE: Photo courtesy of NTSB Major Accident Investigations Division

Figure 3.12--Wiring Deterioration in Older Aircraft

As Figure 3.12 shows, significant deterioration in the integrity of wiring can occur during normal operation. Similar deterioration can also occur in aircraft hydraulic systems.

Most research conducted to date on aging aircraft and their systems quite naturally focuses on first- and second-generation airliners; comparatively less is known about how more-complex aircraft will age. First- and second-generation airliners with servomechanical control systems and limited integration between systems may age more gracefully than newer aircraft equipped with fly-by-wire systems, composite structures, and highly integrated systems.

Although many aviation experts express concern about the operation of aging aircraft, insufficient evidence exists to predict an increased accident rate based on age alone. The airline industry suffers from a lack of quantitative data on which to build trend indicators in relation

over the long term. This and other problems were addressed in wiring-related recommendations made by NTSB Chairman Jim Hall to FAA Administrator Jane Garvey on April 7, 1998, calling for stepped up inspections and repair.

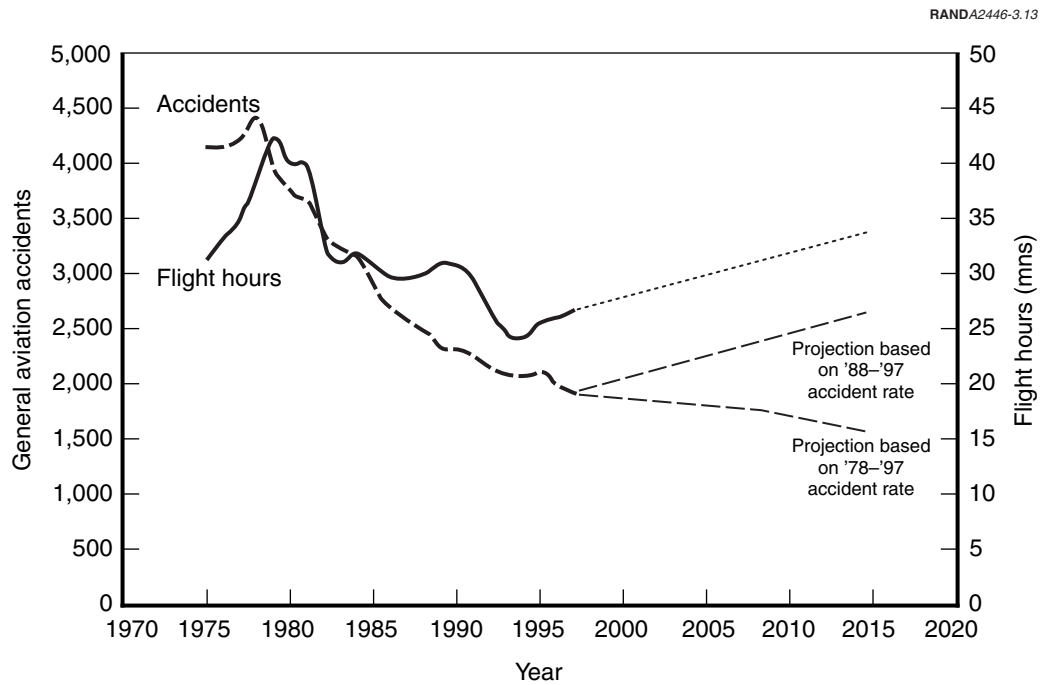
to aircraft aging. For the Air Force, with a fleet of more than 16,000 aircraft, programs such as the ASIP are a viable investment. However, it is more difficult for individual airlines to justify such investments. Without a rich data environment, the correlation between aging and incident/accident rates is unclear. The FAA's National Aging Aircraft Research Program has linked with the Air Force's Aging Aircraft Program Office and NASA's Aging Aircraft Program in an attempt to answer questions related to the effect of age on an aircraft's flight-worthiness.

It is reasonable to expect that the NTSB will experience some increase in incident reports related to events involving aging aircraft and systems. Monitoring events involving aging aircraft should continue to be a high priority within the NTSB. Future incident and accident investigations should attempt to quantitatively establish any emerging trends in this area. The Safety Board also has gained extensive experience with aging systems and has the ability to communicate knowledge and findings to the broader research community through the means of a safety study.

TRENDS IN GENERAL AVIATION

More than 180,000 GA aircraft are in active operation in the United States today. As discussed in Chapter 1, the NTSB currently investigates approximately 2,000 GA accidents each year through its six regional offices and four smaller field offices. This is a very significant factor in the workload of Safety Board investigators and managers. GA flight hours are expected to increase steadily. Reform of liability laws, the current strong economy, and the growing popularity of aviation as a sport have combined to cause a renaissance in GA, reversing a 15-year decline. The projected growth in GA is shown in Figure 3.13 alongside the historical and potential future accident rates.

If the GA accident experience of the past decade occurs in the future, GA accidents could increase as traffic grows. But, if the cumulative accident experience of the past two decades applies, the



SOURCE: Developed from the NTSB Aviation Accident Data Base; and FAA, *Long-range Aviation Forecasts*, June 1998.

Figure 3.13--GA Demand Forecast and Historical Accident Rate

number of accidents could decline. There is no way to definitively assess the future GA accident trend, although we can observe that although the GA accident rate is at its lowest point in history, the rate of decline has slowed and has been relatively flat in recent years.

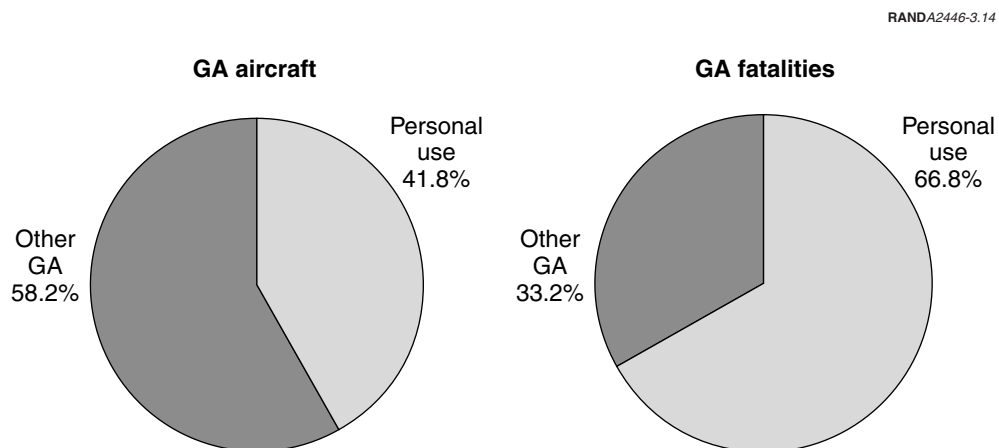
Most of the R&D investments in aviation safety are focused on the air carrier aviation segment. Only modest investment is directed at safety improvements for GA aircraft. This places the burden of further reducing the GA accident rate largely on industry and association initiatives. If such initiatives are not successful, the GA accident rate could rise in proportion to increased flight activity.

Factors other than flying hours alone will impact the nature of GA accident investigations in the future. The variety of air vehicles that will be operating and the amount of technology being integrated into new designs are both growing dramatically. The most significant factor likely to affect the NTSB in the coming years, however, is growth in the number and diversity of personal use aircraft.

As shown in Figure 3.14, personal use aircraft, in addition to being the largest single segment of the GA population, generate more than their share of fatal accidents. Most of these accidents have unremarkable causal trails, but the NTSB is legally obligated to investigate them and to issue reports. A small, but important, percentage of these accidents lead to the identification of significant safety issues and the issuance of industry-wide recommendations.

The diversity of aircraft in the personal use segment is shown in Table 3.2. The personal use category encompasses a wide range of aircraft, from the popular Cessna, Piper, and Raytheon-Beech single and light-twin aircraft, to retired military fighters and trainers, to ultralights.

The diversity of GA aircraft places heavy demands on the skills and experience of NTSB accident investigators. For example, the number of former military aircraft, or "warbirds" as they are called, is steadily growing. In recent years, the warbird segment of GA has expanded to include jet aircraft, some of them capable of supersonic flight. These jets are usually high-performance aircraft designed to meet military standards. GA pilots transitioning to warbirds are often unprepared for the challenge of flying powerful, and in most cases, much less forgiving aircraft. The investigation of an accident



SOURCE: Aircraft Owners and Pilots Association, July 1998, p. 13.

Figure 3.14--Personal Use Aircraft as Percentage of GA Aircraft and GA Fatalities

involving a retired fighter aircraft requires investigators to understand military systems, often of foreign manufacture, that are several decades old.

Table 3.2
Diversity in the Personal Use Aircraft Segment

Type	Approximate Number
Manufactured light Single/Twin	63,000
Vintage/Antique*	36,200
Warbird	4,300
Aerobatic	900
Kit/Homebuilts	10,300
Ultralights	4,600
Lighter-than-air	2,100
Gliders/Parasails	2,100
Rotorcraft	1,500
Total Personal Use Aircraft	125,000

*Aircraft manufactured before 1960.

SOURCES: Federal Aviation Administration, February 1995 and May 1999b; General Aviation Manufacturers Association, 1999; Experimental Aircraft Association Web site (www.eaa.org); Aircraft Owners and Pilots Association Web site (www.aopa.org).

At the other end of the spectrum are kit and homebuilt aircraft. In many respects, these aircraft represent the leading edge of GA aircraft technology. Because these aircraft utilize technology not yet incorporated in production units, the pilot is in essence operating an experimental aircraft, assuming the dual roles of test pilot and flight test engineer. These aircraft often are constructed of advanced composites, use state-of-the-art avionics, and operate with high-power loadings.

Many kit and homebuilt aircraft employ custom fuel and electrical systems, extensive modifications to design plans, and material substitutions. Powerplant technology also varies widely. While most kit and homebuilt aircraft utilize modified air-cooled aircraft piston engines, many are transitioning to converted automotive, modified

snowmobile, and even rotary and diesel engines. In short, very little standardization exists in this segment of aviation.

Sport flying attracts many famous individuals, and accidents involving public figures generate significant national media attention. The deaths of singer-actor John Denver in a homebuilt aircraft and former Air Force General David McCloud in a foreign-made aerobatic aircraft are examples of GA accidents that require extra efforts on the part of the NTSB. The 1999 loss of John F. Kennedy, Jr., and members of his family led to an investigation rivaling that following a crash of a large commercial airliner.

Safety is the primary concern for the future of GA. More than 90 percent of the accidents tracked by the NTSB are in the GA segment, and nearly half of the recorded GA accidents are traced to failures of the flight crew. Flight crew training is therefore a major focus of the FAA's General Aviation Accident Prevention Program. Safety education is also vigorously pursued by organizations representing GA, most notably the Aircraft Owners and Pilots Association (AOPA), which hosts the Air Safety Foundation, and the Experimental Aircraft Association (EAA). The EAA operates a network of affiliate organizations, such as Warbirds of America and the Vintage Aircraft Association, which also conduct safety programs targeted at their flying communities. For example, the numerous warbird accidents have prompted the community of warbird operators to institute an array of safety programs and workshops to promote safer operations.

Another important factor related to safety is that GA flying often occurs in uncontrolled airspace. Historically, high equipment costs have prevented GA aircraft from making use of the extensive radar services currently available. The planned transition to free flight, however, requires more extensive integration of GA aircraft into the airspace system. The advent of GPS, in addition to the development of lower cost, high-reliability electronics, promises to make CNS services more broadly available to the GA community. The FAA, NASA, and avionics manufacturers are cooperatively exploring revolutionary new low-cost systems to automatically alert pilots of traffic conditions and provide cockpit displays showing the flight patterns of other aircraft.

Through these many initiatives, it is probable that GA safety will continue to improve, but the NTSB will likely continue to investigate a large number of these accidents. However, the NTSB's workload will not be affected solely by an increased number of accidents. As with commercial aircraft accidents, investigators will likely face increasing diversity and complexity with GA accidents. The NTSB will be forced to develop new methods of managing the GA workload that ensure both efficient use of staff resources and thorough investigations.

NEW USERS OF THE NATIONAL AIRSPACE SYSTEM

A variety of new vehicle types could become operational during the first decade of the twenty-first century. Because these vehicles will share the civil airspace with other aircraft, NTSB will need to follow their evolution and ultimately become familiar with their designs and operations.

Unmanned aerial vehicles (UAVs) are expected to become more important to U.S. military operations over the current decade. Many of these vehicles are capable of extremely long-range, long-endurance operations (Munson, April 1999). The Teledyne-Ryan Global Hawk, for example, has an operational radius of 3,000 nautical miles and can remain aloft for 24 hours at that radius.

During limited periods of training and deployment, military UAVs will have to share the civil airspace with other aircraft. Public and commercial users also have an interest in exploiting the capabilities of UAVs. Television news organizations, for one, see great potential for traffic monitoring and special event coverage. Long-endurance aircraft platforms, currently under development for use as Internet relay platforms over populated areas, may ultimately evolve to include unmanned aircraft (Platt, June 1999, p. 151).

The DOD is currently working with the FAA to define operational procedures for safely handling UAVs. Integration of commercial systems into UAV platforms is still on the horizon. Resolving these UAV issues with the FAA and its counterpart international organizations is essential to successful realization of the UAVs' potential. Accidents involving most major UAV designs have already occurred, although to date

they have occurred either on military test ranges or in combat operations and have not involved manned aircraft.²⁸

Other new vehicles will begin using the civil airspace. Tilt-rotors, such as the Bell Helicopter Textron 609 civil tilt-rotor, represent a new class of aircraft, combining aspects of fixed and rotary wing aircraft. The aircraft is scheduled to fly in 2001 and enter service in 2003 ("Mating Season," October 2000).

Also proposed are manned and unmanned commercial reusable launch vehicles (RLVs). These vehicles are being conceived to deliver payloads to low earth orbit (LEO) and then reenter the earth's atmosphere to perform controlled landings for subsequent reuse.²⁹ The FAA Office of Commercial Space Transportation has already issued interim safety guidance for these vehicles (Federal Aviation Administration, January 4, 1999). Several approaches for integrating these vehicles into the NAS are under study.

The future of these new reusable commercial vehicles is very uncertain. Some candidate commercial systems, originally scheduled to enter service in the near future, have succumbed to developmental problems, funding shortfalls, or a lack of demand. The marketing problems experienced by LEO telecommunication satellite companies have in particular influenced the decision of many launch system developers to cut back on ambitious deployment plans.

Many of the systems discussed here present long-range issues for the NTSB to contemplate. The NTSB has so far tackled few investigations related to advanced aerospace systems. Planning for new types of operations should be an increasingly important factor in Safety Board training practices in the future.

²⁸Following a March 19, 1999, crash of the Air Force's Global Hawk UAV, the FAA rescinded its certification to fly in commercial airspace (Whitley, April 30, 1999a). The FAA subsequently cleared the Global Hawk to resume flight testing in May 1999 (Whitley, June 4, 1999).

²⁹An optimistic summary of the many RLV concepts currently under consideration can be found in Federal Aviation Administration, May 1999a.

CHAPTER 4
AIR CRASH LITIGATION:
THE LIABILITY ENVIRONMENT IN WHICH THE NTSB OPERATES

Just as aircraft and the systems in which they operate continue to grow in complexity, so too does the legal system within which claims related to air crashes are contested. This complexity has important implications for the NTSB's operations and procedures, particularly the ones that rely on the party process. Isolating the NTSB from the litigation environment is virtually impossible as long as the NTSB relies on the party process to conduct its major investigations and the litigation and resolution of claims substantially depends on NTSB findings.

This chapter discusses the liability environment in which the NTSB operates and evaluates the increasingly partisan role of parties to its investigations. This chapter also considers to what extent the NTSB's "probable cause" finding carries weight in air crash litigation, and whether this finding serves the Safety Board's statutory goal of improving air safety.

The stated mission of the NTSB is to investigate the facts, circumstances, and probable cause of an accident and make recommendations to prevent similar accidents from happening in the future. NTSB investigations occur in an environment surrounded by the aviation liability and claims process. The specter of dozens, if not hundreds, of lawsuits appears as soon as the magnitude of the tragedy becomes apparent. The parties likely to be named to assist in the NTSB investigation are also the most likely to be named defendants in the civil litigation that inevitably follows a major accident.

The investigation process, as important as it is to the safety of the flying public, has unintentionally also become important to the establishment of legal fault and blame. Separating the NTSB investigative process from the litigation process is a well-intentioned idea that is of limited practical utility given the importance of one process to the other. Few limits remain on the use of NTSB reports in civil litigation. As a consequence, NTSB final accident reports,

considered by all sides to be the "roadmaps to liability," figure prominently in court proceedings.

The party process always presents inherent conflicts of interest for entities that are both parties to an investigation and "parties defendant" in related litigation. RAND has found, at least with some accidents, that the party system is potentially unreliable and party representatives may act to further various interests beyond prevention of a similar accident. While certain parties are uniquely able to provide essential information about matters such as aircraft design or airline operations, there are limits to the effectiveness or integrity of the party system in certain kinds of complex accidents.

The most controversial element of the NTSB investigation process is the *statement of probable cause* set forth in the final accident report. Within the NTSB environment, this statement reflects the cumulative fact-finding efforts and analysis in the NTSB investigative process. However, probable cause statements reverberate far beyond the halls of the NTSB, significantly influencing the means for assigning legal fault and blame. Suggestions for improving the accident investigation process are in part to curtail the finger-pointing often associated with the NTSB's determination of probable cause. Many aviation professionals propose, for example, rigorous analytical techniques that examine the complex events that may have caused an accident, which they assert would provide more useful information than focusing on a single probable cause.

CHARACTERISTICS OF AIR CRASH LITIGATION

In 1988, the RAND Institute for Civil Justice (ICJ) published an unprecedented study of air crash litigation and victim compensation. The three-year Aviation Accident Study gathered data that for the first time permitted analysis of litigation outcomes and litigant behavior in difficult cases (King and Smith, 1988a, p. 2). The survey used in the study was derived from the files of insurance carriers and defense lawyers pertaining to the 25 major accidents (aircraft with more than 60 seats or accidents resulting in more than five deaths) involving U.S. carriers from 1970 to 1984. These accidents resulted in 2,228 deaths,

although the analysis took account of only 2,113 claims for which some kind of economic loss could be calculated.

The complexity of aviation accident litigation has evolved as the industry itself has evolved. Early airliners carried only about 60 passengers and were far less technically complex than today's aircraft, some of which can transport 400 or more passengers. For airline passengers, air travel has matured from an adventurous activity that carried with it a certain amount of risk to an everyday event, integral to commerce and leisure, that involves minimal risk. Because airline travel is now so commonplace, juries are inclined to assume that accidents are caused by negligence (Kreindler, 1998, pp. 1-2).

As the perception of the risk involved with air travel has changed, significant changes in the law (including the emergence of the doctrine of *strict liability* in tort law) have created new theories of liability and altered the balance between claimants and aircraft manufacturers or airline operators.

The 1988 RAND study demonstrated that most aviation lawsuits filed in response to major commercial aviation disasters are wrongful death actions for economic and noneconomic damages resulting from the death of a spouse or close family member. In nearly all commercial aviation disasters there are few, if any, survivors among the passengers and crew. Claims, therefore, are primarily for wrongful death and only rarely for personal injuries (King and Smith, 1988a). The complexity of modern aviation makes it difficult to know exactly which entities to sue when an accident occurs, a situation that has resulted in suits against multiple defendants, such as all parties involved in manufacturing, operating, and regulating the aircraft in question (King and Smith, 1988a, p. 8).

Lawsuits can be brought in either state or federal courts, depending on the plaintiff lawyer's assessment of which jurisdiction is more likely to award large damages or whether punitive damages are available. In the federal court system, cases pending in different jurisdictions are combined for pretrial proceedings. When this occurs, a small group of attorney specialists, who have significant collective expertise and clout in negotiating on behalf of potentially dozens of

claimants, is appointed to the plaintiffs' steering committee (King and Smith, 1988a, p. 12).

The claims examined in the 1988 RAND study also revealed that aviation litigation is costly, time-consuming, and more likely than other types of litigation to be resolved with a trial. Of the 2,113 potential claims during the period between 1970 and 1984, actual claims were filed for all but two, and lawsuits were filed in two-thirds of these cases. Although 86 percent of those cases were settled before trial, a higher percentage of aviation cases proceeded to trial (14 percent) than cases for other types of civil litigation (5 percent of which proceed to trial), including other types of personal injury litigation.

Insurance carriers generally took the lead in settling aviation claims by contacting families, handling their claims, and hiring local defense counsel to litigate claims that were not settled. In addition, the RAND study showed that aviation litigation became more contentious over time; the number of claims filed during this 14-year period was unprecedented. These trends are significant for the NTSB. With more at stake, the importance of the outcome of the NTSB investigation to the potential liability of the defendants becomes evident.

The stated position of insurers following an accident is spelled out in a Funding Agreement.¹ In most major commercial aviation litigation, the insurance company that has assumed most of the risk for the airline takes the lead in controlling the case and handling claims. Typically, however, multiple defendants are named in the lawsuits. In virtually all cases studied in the 1988 report, the airline in question was sued, but the aircraft manufacturer, engine manufacturer, airport

¹A *funding agreement* is an agreement between persons and/or entities potentially liable for damages to one or more claimants whereby the parties agree to share in the payment to settle a judgment. A funding agreement is intended to expedite the resolution of claims. Such arrangements require each party to recognize its potential liability based on its own preliminary investigation or participation in the NTSB process. Early in an investigation, there may not be sufficient information to justify a final commitment to specific dollar amounts, or specific percentages of settlements or judgments (Confidential interview with a leading aviation insurance executive, December 6, 1999; King and Smith, 1988a, pp. 8-9; Hilliard, 1996; Hunt, Irvine, and Stoll, 1986).

authority, or government agencies, such as the FAA or the U.S. Weather Service, were also named as defendants. After the airline, the aircraft manufacturer was the second most frequently named defendant. Commercial air crash litigation is unique in that it exposes the defendants--most often the airline or the aircraft manufacturer--to the risk of being held liable for many deaths. In addition to imposing multimillion dollar jury awards, such litigation is usually highly publicized, exposing defendants to adverse publicity that could jeopardize their competitive business positions.

The high-stakes nature of this kind of litigation is intensified by the demographic makeup of air passengers. The 1988 RAND study determined that air crash victims differ from the general U.S. population in ways that translate into higher compensation for their deaths (Kakalik et al., 1988, p. 86). For example, based on the data collected from 1970 to 1984, air crash victims were predominantly married men in their prime earning years (age 30 to 59). Many were highly paid professionals or executives with incomes nearly twice the U.S. average. In addition, roughly 40 percent of the claims involved multiple deaths in the same family.

THE CHANGING FACE OF AVIATION LITIGATION

The 1988 RAND study has not been updated, nor has any subsequent published research delved further into the subject of air crash litigation and victim compensation. For example, there has been no reported examination of the correlation between the length of an NTSB investigation and delays in resolving aviation victim claims. Because the information needed to update the research is proprietary and belongs to a handful of aviation insurers and defense law firms, any discussion of the changing nature of airline accident litigation is limited to anecdotal information from attorneys and insurance executives willing to share their experiences and insights.

For the present study, RAND conducted confidential interviews with plaintiff and defense lawyers involved with litigation related to recent major commercial aviation accidents and insurance executives who have

handled such claims. These interviews reveal some important trends in aviation litigation, which are discussed in the following sections.

Fewer Early Settlements

Very few, if any, claims for compensation are now settled without the involvement of a lawyer. Generally, the airline's insurance company takes the lead in negotiating and paying compensation on behalf of all potential defendants (Whalen, 1998). This process begins shortly after the accident occurs, after the insurer contacts the family members of deceased passengers. Although no statistics are available to support this, defense lawyers and insurance executives agree that in today's litigious climate few of these initial contacts would lead directly to settlements. The increased cohesiveness of family support groups gives the victims' families access to information about the legal process and seems to play a part in reducing the number of settlements that can be achieved without the participation of a plaintiff's attorney.

In an earlier era, surviving family members were typically represented by their family lawyers who were not necessarily experts in the complexities of aviation litigation. Now, however, such family advisors are more likely to simply help claimants find lawyers who do specialize in aviation cases. The engagement of a specialist reduces the likelihood of early settlement and may ultimately result in payment of higher compensation to claimants.

In addition, at least one family support group is usually formed after a major commercial aviation accident. Such groups provide essential support and counseling for grieving family members through the Internet or other channels of communication. Family support groups also facilitate communication among claimants about the prospects for legal action against an airline or other possible defendants and they enable families to exchange information about plaintiffs' attorneys. In some instances, such communication has promoted groups of claimants to seek collective representation, thereby seriously diminishing the likelihood of early individual settlements without legal action.

Fact-Finding Through Litigation

One of the principal motivating factors behind claimants seeking recourse through the tort system is their simple desire to "find out what happened" (Hensler, 1998, pp. 159-160). Nowhere is this motivation more prevalent than among surviving family members of victims of a major commercial air crash.

Several factors contribute to the zeal with which air crash claimants seek knowledge of the factual circumstances of the accident through the civil litigation process. First, and possibly most important, claimants are specifically barred from participation as parties in the NTSB accident investigation. Plaintiffs and their attorneys are prohibited from observing the collection of physical evidence, the testing of component parts, and any other aspect of a complex investigation that may take many months or years to complete.² Nor do plaintiffs' experts contribute to or participate in the NTSB investigation.

On the other hand, the defendants (the airline, the aircraft or component manufacturer, air traffic controllers, or others) are extensively involved in every aspect of the NTSB process, serving on groups organized by the NTSB to determine the facts of the accident. Often, the very parties who are defendants in a related legal action conduct critical tests for the NTSB, leading to charges that the results of such tests are biased and untrustworthy. Additionally, in some instances, NTSB investigations can take up to two or more years to complete only to result in inconclusive or incomplete findings about the probable cause of an accident. In these circumstances, civil litigation, with the promise of extensive discovery, remains the only other avenue by which family members may uncover "what happened" to cause the accident.

²In *Graham v. Teledyne-Continental Motors*, 805 F.2d 1386 (9th Cir. 1986), the court upheld the refusal of the NTSB to permit a representative of the pilot's estate to participate in or observe the NTSB's testing and disassembly of the engines involved in a fatal GA accident.

Contested Liability

In many, if not most, aviation accident cases, the defendants offer to stipulate to liability in exchange for an agreement by the plaintiff to waive punitive damage claims. Such offers are usually made when the NTSB investigation is concluded and the determination of probable cause, backed by extensive factual findings, makes it evident that the defendant is unlikely to escape liability. Conversely, the NTSB findings may suggest that an accident was not caused by sufficient misconduct to support an award of punitive damages.

In the absence of a liability contest, the only issue to be resolved through litigation is the amount of compensation to be paid. However, buoyed by claimants who are more interested in determining "what happened" than in immediate compensation, some plaintiffs' lawyers are now more willing to refuse to accept such stipulations of liability. This strategy affords litigants the opportunity to engage in extensive discovery and possibly find different (and more damaging) facts than were uncovered by the NTSB investigation.

At a minimum, the threat of extensive discovery--which can require the production of a considerable amount of documentation and the interrogation of top-level corporate executives--provides plaintiffs with additional leverage when it comes to settlements. If a case goes to trial, evidence of the defendants' wrongdoing is likely to produce higher jury awards than if the evidence is limited to economic valuation of the compensation claim.

Escalating Jury Awards and Insurance Settlements

Recent settlements and jury awards illustrate the high stakes and high visibility surrounding aviation accident litigation.

- More than \$1 billion was paid in total compensation and litigation expenses with respect to deaths and injuries in the 25 aviation accidents considered in the 1988 RAND study--an average of \$42 million per accident. Today, jet aircraft carrying 150 passengers or more are insured for an average of \$500 million to \$1 billion, the anticipated payout in the event of a single catastrophic accident.

- Twenty-one claims stemming from the 1994 crash of American Eagle Flight 4124 in Roselawn, Indiana, were settled in federal district court in Chicago in 1997 for more than \$110 million.
- A state court jury in Cook County, Illinois, awarded \$28.2 million to the surviving widow of a 71-year-old man killed in the crash of United Airlines Flight 232 in Sioux City, Iowa, in 1989. The widow was also injured in the crash. The damages were primarily awarded on the basis of the pain and suffering of the plaintiff, as well as for the wrongful death and suffering of her elderly husband. Several plaintiff and defense lawyers interviewed by RAND pointed to this case as evidence that juries are more willing than in the past to award high levels of damages in cases involving senior citizens, especially when pain and suffering during the crash sequence can be demonstrated.

Another indication of the rising cost of major commercial aviation accidents is the aggregate sums paid by insurers to cover hull losses and liability. As indicated in Figure 4.1, worldwide hull and liability losses for major commercial accidents have risen dramatically since 1980, escalating from approximately \$500 million in 1980 to almost \$2 billion in 1998 (Airclaims, LLP, 1998).

The Use of NTSB Materials in Civil Litigation

Since the inception of the NTSB as an independent investigative organization, efforts have been made to prevent the agency's work product--including opinions and conclusions regarding the cause of aviation accidents and other transportation mishaps--from being used in civil litigation. In most aviation accident cases, one or more of the litigants seeks to introduce some part of the NTSB's work into evidence, usually to establish facts that are uniquely within the possession of the on-scene investigator or to offer "factual findings" as a possible foundation for determining legal fault and liability (Kreindler, 1998, p. 19-4).

Litigants may attempt to introduce into evidence NTSB factual reports and summaries, data compilations, photographs, flight and

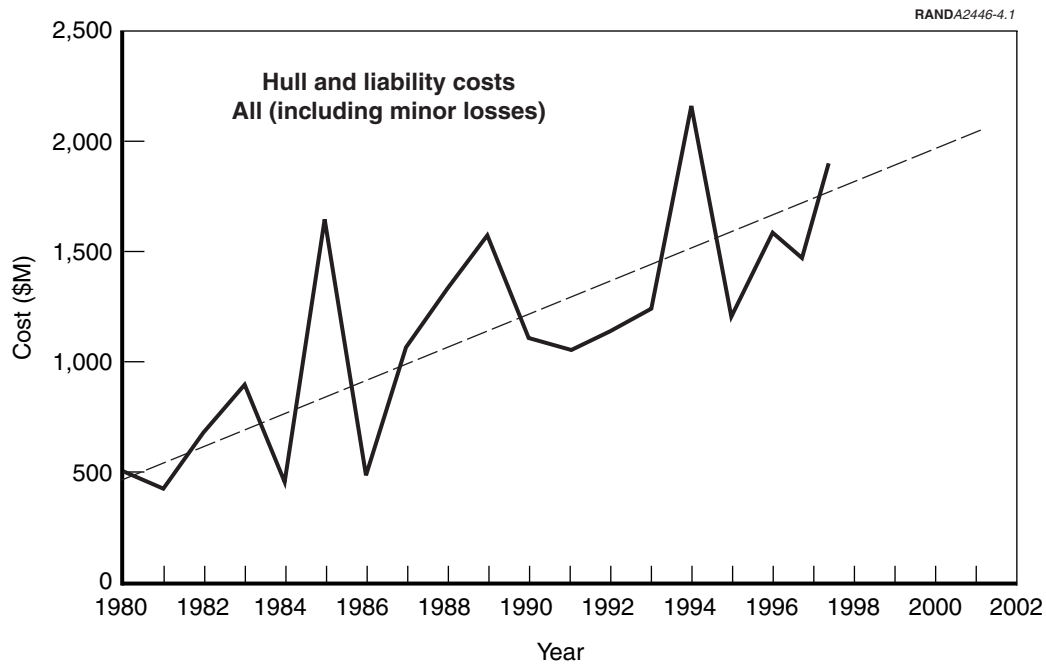


Figure 4.1--Worldwide Hull and Liability Costs, 1980 to 2002

maintenance records, or CVR and FDR transcripts, or obtain the testimony of NTSB investigative personnel (Miller, Winter 1981, pp. 279-284; Atwood, 1987).

Section 701(e) of the Federal Aviation Act of 1958 (49 U.S.C. 1441[e]) and Section 304(c) of the Independent Safety Board Act of 1974 (49 U.S.C. 1903[c]) preclude the use or admission into evidence of any NTSB report "relating to any accident or the investigation thereof," in "any suit or action for damages growing out of any matter mentioned in such report." Current regulations limit the testimony of Safety Board employees to the factual information obtained during the course of an investigation, including evaluations embodied in their accident reports.

Investigators are prohibited from testifying in court; such testimony is available only through depositions or written interrogatories. Because NTSB employees are authorized to testify only once in connection with an accident investigation, all interested parties must attend that single deposition, no matter how many lawsuits have been filed. Consistent with these provisions, NTSB employees are

forbidden to use an NTSB Accident Report for any purpose during their testimony.³

Several justifications support the limitations on using NTSB materials in civil litigation. Although the legislative history of this provision is sparse, the apparent congressional intent of 49 U.S.C. 1441(e) was to ensure that the NTSB (and its predecessor agencies) did not supplant the role of the judge and jury in determining the cause of accidents and to encourage accurate and independent accident investigation by keeping the NTSB apart from any determination of liability (Kreindler, 1998, §19.01[1]; Campbell, 1996).⁴ In addition, it was assumed that witnesses would not disclose facts completely and honestly to investigators unless they were guaranteed confidentiality. Finally, the NTSB's limited resources would be drained if investigators spent too much of their time testifying in civil damage suits.

Whereas the basic rationale for limiting the use of NTSB reports within the context of litigation remains valid, such well-intentioned designs to isolate the NTSB from the litigation environment ultimately have limited utility. As described by a former general counsel of the NTSB, these rules are intended to strike a balance between the legitimate needs of litigants to discover factual information within the exclusive control of NTSB personnel and the need of the NTSB to conserve its resources and avoid the "entanglement of its prestige and neutrality in litigation" (Campbell, 1996, p. 12). However, the NTSB's findings regarding the probable cause of a major commercial aviation accident are ultimately so important to the determination of legal fault that such neutrality is difficult, if not impossible, to maintain.

These issues pose a fundamental question: How much of the NTSB's data can be used to help prove a claim or to defend or impeach a witness? As detailed in Chapter 2, the NTSB develops two types of reports: a detailed "factual file" containing Working Group factual reports, test results, testimony from hearings, and other data (which is

³49 CFR 835.3 and 835.5.

⁴*Universal Airline, Inc. v. Eastern Air Lines, Inc.*, 188 F.2d 993 (D.C. Cir. 1951); *Lobel v. American Airlines, Inc.*, 192 F.2d 217 (2d Cir. 1951).

sometimes very extensive) collected by investigators; and the NTSB Blue Book report containing facts, analysis, findings, and a statement of probable cause.

The earliest interpretations of 49 U.S.C. §1441(e) held that written reports could not be admitted into evidence, but judges could compel investigators to *testify* to the facts surrounding an accident and the on-site investigation.⁵ *Lobel v. American Airlines, Inc.*, and numerous cases thereafter, held that admission of an investigator's factual report is permissible in so far as the report "contained no opinions or conclusions about possible causes of the accident or defendant's negligence."^{6,7}

Rejecting a literal interpretation of the precursor to §1441(e), the *Lobel* court found that the intention of the provision was to guard against the introduction into evidence of agency views on "matters which are within the functions of courts and juries to decide." More recent decisions have held that the statute only excludes conclusions regarding the probable cause of an accident, approving the general admissibility of the rest of an NTSB "Blue Book."⁸

Although the predominate view allows for the general admissibility of all materials produced by the NTSB other than conclusions or opinions as to probable cause, a minority of courts have interpreted §1441(e) as an absolute bar to admission of any part of an NTSB report, other than a "Factual Accident Report."⁹ In the *Sioux City* litigation, the plaintiffs sought to introduce at trial the entire NTSB "Aircraft Accident Report" containing a compilation of all the factual information uncovered in the

⁵*Universal Airline, Inc. v. Eastern Air Lines, Inc.*, 188 F.2d 993 (D.C. Cir. 1951).

⁶*Lobel v. American Airlines, Inc.*, 192 F.2d 217 (2d Cir. 1951).

⁷*Berguido v. Eastern Air Lines, Inc.*, 317 F.2d 628 (3rd Cir. 1963); *Fidelity & Casualty Co. of New York v. Frank*, 214 F.Supp. 803 (D CT 1963); *American Airlines, Inc. v. U.S.*, 418 F.2d 180 (5th Cir. 1969).

⁸In re Air Crash Disaster at Stapleton International Airport, Denver, Colorado, on November 15, 1987, 720 F.Supp. 1493 (D. CO 1989); in re Air Crash Disaster at Charlotte, North Carolina, on July 2, 1984, 982 F.Supp. 1071 (D. S.C. 1996).

⁹In re Air Crash Disaster at Sioux City, Iowa, on July 19, 1989, 780 F.Supp. 1207 (N.D. IL 1991); in re Air Crash Disaster Near Roselawn, Indiana, on October 31, 1994, 1997 WL 572896 (N.D. IL 1997).

investigation, along with an analysis of the factual data and numerous conclusions about alternative or competing theories of causation. The court held that "the unequivocal wording of sections 1441(e) and 1903(c) appears to leave no room for creative interpretation. The language on its face states an absolute bar to the use of NTSB reports in the present action." The decision did not specifically address the admissibility of factual accident reports, although other courts have read *Sioux City* as an absolute bar to *any* reports generated by NTSB employees.¹⁰

In an effort to clarify the confusion over the admissibility of reports generated by the NTSB, on December 17, 1998, the NTSB issued amendments to 49 C.F.R. Part 835. The amendments attempt to clarify the use of Safety Board reports in litigation. As amended, the new regulation defines "Board accident report" and "factual accident report" as follows:

- **Board accident report** refers to the report containing the Safety Board's determinations, including the probable cause of an accident, issued either as a narrative report or in a computer format ("briefs" of accidents). Pursuant to section 701(e) of the Federal Aviation Act of 1958 (FA Act), and section 304c of the Independent Safety Board Act of 1974 (49 U.S.C. 1154[b]) (Safety Act), no part of a Safety Board accident report may be admitted as evidence or used in any suit or action for damages growing out of any matter mentioned in such reports.
- **Factual accident report** refers to the report containing the results of the investigator's investigation of an accident. The board does not object to, and there is no statutory bar to, admission in litigation of factual accident reports. In the case of a major investigation, group chairman factual reports (see Chapter 3 for more information) are factual accident reports.

¹⁰*Daniels v. Tew Mac Aero Servs.*, 675 A.2d 984 (ME 1996); *Trans States Airlines v. Pratt & Whitney Canada, Inc.*, 1995 U.S. Dist. LEXIS 1641 (N.D. IL, 1995).

These amendments attempt to create a clear line between factual investigators' reports and reports containing the Safety Board's conclusions. The provisions seem to indicate that an investigator's opinions and conclusions contained in the factual accident report will not be barred by the statute, although an NTSB employee will only be allowed to *testify* as to factual information (Stern, Winter/Spring 1999).

A recent decision by the U.S. Court of Appeals for the District of Columbia Circuit may go even further toward resolving the issue of the use of NTSB Accident Reports in litigation. In *Chiron Corp. and Perseptive Biosystems, Inc. v. National Transportation Safety Board*, 198 F.3d 935 (D.C. Cir. 1999), parties to an NTSB investigation sought to obtain information about cargo being carried aboard a Federal Express flight when the NTSB decided not to share such information. The petitioners claimed that they were entitled to such material because the factual portion of the NTSB Accident Report might eventually be admitted as evidence in a lawsuit that Federal Express had filed against them.

As an initial matter, the D.C. circuit court rejected the premise that the NTSB report itself would be admissible in a civil lawsuit. The court found that Congress had explicitly provided that "no part of a report of the Board, related to an accident or an investigation of an accident, may be admitted into evidence or used in a civil action for damages resulting from a matter mentioned in the report (49 U.S.C. §1154[b])."

Siding with decisions from the Fifth, Ninth, and Tenth Circuits, the D.C. circuit court held that "under the plain terms of the statute, NTSB reports are inadmissible in civil litigation."¹¹ Finding prior judicial distinctions between "factual findings" and "reports of the Board" to be "judicial mislabeling," the court determined that the amended NTSB regulations had clarified the permissible use of the two types of materials. Given accident victims' unquestionable access to

¹¹198 F.3d at 941; *Campbell v. Keystone Aerial Surveys, Inc.*, 138 F.3d 1996 (5th Cir. 1998); *Thomas Brooks v. Burnett*, 920 F.2d 634 (10th Cir. 1990); *Benna v. Reeder Flying Serv., Inc.*, 578 F.2d 269 (9th Cir. 1978).

necessary factual information, the D.C. circuit court held that the courts no longer needed to employ an "exception" to the statute to protect parties in litigation.

NTSB reports have also been barred from use as evidence because of the "hearsay" nature of the materials or testimony. Typically, *hearsay* is defined as "an out of court statement offered to prove the truth of the matter asserted therein." However, Federal Rules of Evidence (FRE) 803(8) provides an exception to the hearsay rule for "public records and reports" setting forth "factual findings resulting from an investigation made pursuant to authority granted by law, unless the sources of information . . . indicate lack of trustworthiness."

In interpreting the hearsay rule, courts questioned whether "factual findings" included "opinions or conclusions." This "arbitrary distinction" was considered by the U.S. Supreme Court in *Beech Aircraft Corp. v. Rainey*, a case concerning the admissibility of evaluative opinions contained in a Judge Advocate General's report as to the cause of the crash of a Navy aircraft.¹² The Court held that the foundation for such a distinction between fact and opinion was questionable, particularly in the context of an aviation accident investigation, where factual findings might often include conclusions or opinions that flow from an investigation by reasonable inference. The "trustworthiness" inquiry, and not an artificial distinction between fact and opinion, was determined to be the primary safeguard against the admission of unreliable evidence.

Under the scheme adopted by the NTSB, the distinction between "fact" and "opinion" forms the basis for decisions regarding the use and admissibility of NTSB reports.¹³ The Court's semantic analysis of FRE 803(8) in *Beech Aircraft* should serve as a warning against the false belief that the differentiation between fact and opinion is particularly meaningful:

It has frequently been remarked that the distinction between statements of fact and opinion is, at best, one of degree;
"All statements in language are statements of opinion, i.e.,

¹²488 U.S. 153 (1988).

¹³See 49 CFR 835.2 and 835.3.

statements of mental processes or perceptions. So-called statements of fact are only more specific statements of opinion. . . ." Surely this "factual finding" could also be characterized as an opinion, which the investigator presumably arrived at on the basis of clues contained in the airplane wreckage. Rather than inquiring that we draw some inevitably arbitrary line between the various shades of fact/opinion that invariably will be present in investigatory reports, we believe the Rule instructs us--as its plain language states--to admit reports . . . setting forth . . . factual findings. The Rule's limitations and safeguards lie elsewhere. . . .¹⁴

Four major factors govern consideration of the trustworthiness of government investigative reports, such as NTSB Accident Reports:

- the timeliness of the investigation
- the investigator's skill or experience
- whether a hearing was held and the level at which it was conducted
- possible bias and motivation problems, such as whether the report was prepared with a view to litigation.¹⁵

If any portion of an NTSB report passes this inquiry and falls outside the limitations of §1441(e), it should be found to be admissible, provided it is not found to be prejudicial or irrelevant to the proceedings.

Disputes about the admissibility of NTSB materials are common. In fact, almost every recent case involving a major commercial aviation accident has involved some preliminary disputes about the use of NTSB reports before or during trial.¹⁶ Although these exclusionary provisions lie at the core of the NTSB's effort to remain outside the fray of civil litigation, the NTSB rarely gets directly involved in the struggles over admission of its reports. For example, the NTSB has never filed an *amicus* brief with any court seeking a strict interpretation of §1441(e). Ironically, it would appear that the U.S. Department of Justice,

¹⁴488 U.S. 153 (1988) at 168-169.

¹⁵Fed R. Evid 803(8) and related commentary.

¹⁶In *re* Air Crash Disaster at Sioux City, Iowa, on July 19, 1989, 780 F.Supp. 1207 (ND IL 1991); in *re* Air Crash Disaster near Roselawn, Indiana, on October 31, 1994, 1997 WL 572896 (N.D. IL 1997); in *re* Air Crash Disaster at Charlotte, North Carolina, on July 2, 1984, 982 F.Supp 1071 (D. S.C. 1996).

representing the interests of the FAA (a frequent defendant in air crash cases), often seeks broad admissibility rulings for NTSB materials.¹⁷

Although NTSB investigators are frequently called upon to testify in civil proceedings, they are prohibited from giving expert or opinion testimony of any kind. Statements made by the NTSB's general counsel and top investigators imply that the NTSB attempts to maintain this distinction because offering testimony of opinion may erode its impartial posture toward the parties in litigation. NTSB policy allows NTSB counsel to accompany an employee to a deposition only once; after this initial deposition, employees are "on their own" (Campbell, March 1999). It is fair to say that sophisticated private lawyers representing parties in high-stakes aviation litigation make every attempt to exploit this situation, hoping to cross the thin, if not indefinable, line between factual and opinion testimony.¹⁸

NTSB Reports Are "Roadmaps to Liability"

The scheme of regulation that controls the use of NTSB reports in litigation, as well as the permissible testimony of NTSB employees, was devised to reduce or eliminate the NTSB's entanglement with private litigation. However, RAND's examination of this proposition has demonstrated that prior regulations have been of dubious value. As detailed earlier in this chapter, NTSB Accident Reports, factual reports, and other documents have been regularly admitted into evidence in private litigation for a variety of purposes.¹⁹

NTSB employees are frequently called upon to testify about the nature and extent of their investigations, often providing the only information that is available about the on-site investigation, the condition of the wreckage, component test results, and other critical

¹⁷Confidential interview with Department of Justice attorney, Civil Division, Torts Branch, September 1998.

¹⁸Confidential interviews with plaintiffs' aviation attorneys, September 1998 and June 1999.

¹⁹It should be noted that the reports and submissions of any of the parties participating in an investigation, including possible defendants such as the airline, aircraft or component manufacturer, or the FAA, are admissible at trial as party admissions under FRE 1007 and related state evidence rules.

issues. Given the difficulty of clearly distinguishing "fact" from "opinion," it is not surprising that the attorney for one side may press an NTSB witness to testify to "fact" and that the attorney for the other side may object on the ground that the question calls for "opinion."

Because NTSB materials are commonly used in litigation, these reports are increasingly important to the outcome of high-stakes aviation cases. It remains to be seen whether the revised NTSB regulations, combined with much stricter judicial interpretation of the statutory prohibition on the use of NTSB Accident Reports in litigation, reduce litigants' reliance on these materials to any meaningful degree. Numerous lawyers, for both the plaintiff and the defense, refer to the NTSB Accident Reports as "roadmaps to liability." In this sense, admissibility of the reports as evidence at trial is secondary to the quantity and value of the information they contain. The facts, analysis, findings, and statement of probable cause set forth in NTSB "Blue Books" provide indispensable guidance about who might be at fault in an accident and why.

For plaintiff lawyers, whose clients have been excluded from the investigation process, the Accident Report and related factual materials tell them where to begin their own investigation in preparation for litigation. For instance, the Accident Report suggests areas of inquiry to pursue and expert witnesses to call, and helps plaintiffs' attorneys evaluate the merits of the case against particular defendants.

Without the availability of this "roadmap," plaintiffs' lawyers might be forced to commence their investigation into the cause of an accident with limited resources, forcing them to essentially "reinvent" the investigation that has already been exhaustively conducted by the NTSB. This very disparity between the availability of evidence on the side of the plaintiffs (who were not at the crash scene) and the defendants who may have access to information about the aircraft, has caused some courts to take note of the social benefits to be achieved by admitting NTSB reports into evidence, promoting the efficient resolution

of claims and holding down costs for civil litigants with limited funds (Kreindler, 1998, p. 19-5).²⁰

EVALUATING THE PARTY PROCESS

Through the party process, the NTSB leverages its own resources by calling upon outside expertise to assist in determining the cause of an accident. Under this system "persons, government agencies, companies, and associations whose employees, functions, activities, or products were involved in the accident," are specifically included in the investigations, along with others who "can provide qualified technical personnel."²¹

The party system is essential to the NTSB investigative process. Without the input and expertise of the parties it is unlikely that the NTSB would have the technical capability to determine the cause of complex aviation accidents (Goglia, September 15-16, 1998). During the field investigation and throughout the fact-finding process, party representatives play a significant role in evaluating physical evidence from the crash and developing a complete and accurate factual record of the accident. This record serves as the basis for the NTSB's determination of probable cause (National Transportation Safety Board, 1998a; Pangia, 1995).²²

The Role of Parties

The purpose of the party system is to allow those with specialized knowledge to aid in the investigation. Generally, this means aircraft owners and operators, airframe manufacturers, engine and component manufacturers, the FAA, and union representatives. According to NTSB regulations, no party to the investigation "shall be represented by any person who also represents claimants or insurers"; that is, "persons who have interests beyond the safety objective of the investigation."²³ This provision has been interpreted to bar injured passengers, the estates of

²⁰Also, *Gibson v. National Transportation Safety Board*, 118 F.3d 1312 (9th Cir. 1997).

²¹49 C.F.R. 831.11(a).

²²Also, confidential interviews with NTSB IICs, December 1998.

²³49 C.F.R. 831.11.

deceased passengers, or insurance companies from party status. This common interpretation of the rule does not, however, take into account the fact that parties (as defendants) can become "claimants" against each other.

Participants in a Safety Board investigation must have qualifications that relate to specific factual information or skills that would not otherwise be available to the Safety Board. Party representatives are assigned to the appropriate Working Groups and are expected to remain with the investigation until it is completed or until released by the group chairman or the IIC. In complex cases, accredited representatives can be involved with an investigation for months or even years. Working Group members help develop the findings of fact relevant to their areas of expertise and help write the group chairman's factual report.

Party representatives to NTSB investigations are required to sign a written declaration stating that participation is not "on behalf of either claimants or insurers" and that "participation is not for the purposes of preparing for litigation." Nevertheless, it is acknowledged in this declaration that any information obtained may ultimately be used in litigation. Further, the declaration states "it is understood . . . that this form is not intended to prevent the undersigned from participating in litigation arising out of the accident" or to require the declarant to disclose privileged communications with counsel.²⁴ These rules are designed to be sufficiently stringent to ensure that the safety mission of the NTSB is the only focus of an investigation. Party representatives are required to be responsive to NTSB investigators and staff and may lose their party status, and be expelled from the investigation, if they do not comply with their assigned duties or if they conduct themselves "in a manner prejudicial to the investigation" (National Transportation Safety Board, 1998a).²⁵

Despite the intent of the NTSB party rules, the letter and spirit of this mandate are sometimes violated. The exclusion of claimants and the restrictions against litigation may help investigators focus on

²⁴The Party Pledge is shown in Appendix C of this report.

²⁵Also, 49 C.F.R. 831.11(a)(1).

fact-finding during the critical early phase at the crash site.²⁶ However, technical experts representing and employed by the potential defendants may be motivated to influence the investigative outcome from the very outset, or may be induced to do so by the "lawyers behind the door" (Arslanian, September 1998).

The "lawyering" of NTSB investigations puts the integrity of the entire investigative process at risk. Although the practice is specifically excluded by regulation, it is no secret that lawyers for the parties closely track the ongoing investigation. Attorneys, some of whom have substantial experience in cases involving complex accidents, may attempt to shape the story of the tragedy to reflect their client's point of view.

Safety Board investigators and other party participants report that a productive synergy exists during the first few days of an investigation, but then rapidly dissipates once the parties' (defendants') legal departments get "cranked up." It has been obvious to investigators at recent crash sites that party representatives are being "debriefed" by their attorneys during the initial working phases of the investigation, often in the same hotel or other facility where the NTSB's work is taking place (Goglia, September 15-16, 1998).²⁷

Some party representatives conscientiously pursue their responsibilities with the motivation of preventing future accidents. However, others contend they have little choice but to respond to the dictates of corporate managers who are equally, if not more concerned, about the potential liability and corporate image problems associated with a major plane crash.²⁸ Even though the Safety Board's own regulations declare that accident investigations are "fact-finding proceedings with no formal issues and no adverse parties," and that they are "not conducted for the purpose of determining the rights or

²⁶Confidential interviews with NTSB IICs, December 1998.

²⁷Also, confidential interviews with aviation insurance executives, December 1998; confidential interviews with aviation defense lawyers, July 1998 and January 1999.

²⁸Confidential interviews with party representatives, USAir Flight 427, September 1998; confidential interviews with party representatives, United Flight 585, December 1998.

liabilities of any person," in the case of major commercial aviation accidents, the NTSB investigation is, in practice, the starting point for the assignment of fault.²⁹

The involvement of insurers in the investigative process poses similar questions about conflict of interest. Despite clear restrictions on their participation, the NTSB has routinely granted insurance company representatives access to accident scenes because the costs of salvage recovery and wreckage removal are usually covered by an airline's liability insurance policy (Flight Safety Foundation, December 1994; Miller, Winter 1981).³⁰

Insurance representatives arrive on the scene almost as soon as NTSB investigators, offering their assistance and cooperation, and at the same time obtaining almost immediate access to the crash site, access that is not available to any other party or claimant. In confidential interviews, senior NTSB investigators readily admit that, despite NTSB regulations, they are "happy to have the insurers show up." The insurers offset costs and provide necessary support to the investigation, including heavy machinery, communications equipment, computers, and accommodations.³¹ The insurers, their investigators, and their lawyers immediately develop theories of causation, upon which they base a preliminary "funding agreement" to allocate payment of compensation to victims. These theories also provide a foundation to begin developing litigation defense strategies (Mathews, September 15-16, 1998).³²

To many plaintiffs' attorneys and surviving family members, this special access afforded insurance investigators and their lawyers is particularly disturbing. Families who are dealing with the immediate tragedy have no way to obtain information about the cause of the accident, other than through NTSB family briefings and other public

²⁹49 C.F.R. 831.4.

³⁰Confidential interviews with aviation insurance executives, December 1998; confidential interviews with NTSB investigators, November-December 1998.

³¹Confidential interviews with NTSB IICs, December 1998.

³²Also, confidential interviews with NTSB investigators, November-December 1998; confidential interviews with aviation insurance executives, December 1998.

information efforts. Yet, at the same time, attorneys for the parties readily obtain extensive information through their party representatives or from insurance investigators. In practice, company representatives and their lawyers conduct a parallel investigation that shadows the work of the NTSB, providing extensive preparation for civil litigation. Family members view this as more than just an unfair strategic advantage; it leads directly to distrust of the NTSB investigative process.³³

The Role of Parties in Fact-Finding

Party representatives are also involved in the inspection and testing of physical evidence. This phase of the fact-finding process can take months, even years, to complete. NTSB investigators have exclusive authority to decide the way in which any testing will be conducted, including the type of test and who will witness it. Participation in such activities is limited to the relevant parties; again, claimants have no role, even as observers.³⁴

Frequently, aircraft parts must be examined at the manufacturer's facility, where unique test equipment and analytical tools are available.³⁵ Manufacturers and airlines maintain their own accident investigation departments, employing skilled investigators in many disciplines. Parties to the investigation are encouraged to submit their interpretations of findings to the NTSB (National Transportation Safety Board, 1998a).³⁶ These submissions, which can include theories about probable cause and proposed safety recommendations, are often timed to

³³Meeting with 15 family representatives, Washington, D.C., December 1998; submission of Gail Dunham; submission of Maureen and Ken Dobert, CT-43 families, January 21, 1999. RAND held a meeting in Washington, D.C., with victims' families during which several representatives submitted material to the research team. "CT-43 families" is a group title denoting the victims' families following the crash of an Air Force CT-43 transport plane in Croatia.

³⁴*Graham v. Teledyne-Continental Motors*, 805 F.2d 1386 (9th Cir. 1986).

³⁵For example, Boeing Commercial Aircraft maintains test facilities and equipment valued at more than \$500 million, much of it uniquely capable of analyzing Boeing aircraft or component parts.

³⁶Also, 49 C.F.R. 831.14(a).

persuade NTSB investigators to regard the merits of one causation theory over another.

The conflicts of interest inherent in the party process inevitably cast doubt on the accuracy of equipment testing or any other "neutral" fact-finding performed under the aegis of party representatives. Such suspicion is heightened by the technical complexity of modern jet aircraft that is the subject of the NTSB's most difficult and time-consuming investigations, and by the difficulty of independent verification of party submittals.

Clearly, an airline or manufacturer knows more about the engineering, design, or operation of its own aircraft than any NTSB investigator, no matter how experienced. The motivation for parties to withhold information that might be relevant to the cause of the accident, or to deflect attention from an area of possible culpability, is obvious. The question is whether, in fact, this occurs.

RAND researchers collected much anecdotal evidence suggesting that full disclosure of relevant information by parties during major investigations cannot always be assured. For example, representatives of an aerospace company insisted that the company's only interest was in finding the cause of an accident so that safety improvements could be implemented as soon as possible; liability was declared to be of no concern. However, NTSB investigators reported instances of misrepresentation and outright lying by the company's party participants, uncovered only because of the NTSB staff's extensive knowledge.

In another case, one party representative in the investigation of TWA Flight 800 attempted to remove parts from the wreckage reconstruction site; a criminal investigation of this episode is now pending.³⁷ In addition, much of the evidence and expertise resides with parties who may be reluctant to be forthcoming. Senior NTSB

³⁷An airline representative assigned to assist in the crash investigation was indicted for removing materials from the site where the plane was being reconstructed. The NTSB considered various sanctions against the airline, including its removal as a party to the investigation, but no such action was taken (confidential interview with NTSB senior official, February 1999).

investigators concur that parties may eventually convey critical information if asked the right questions, but that sometimes information is not volunteered. This emphasizes the importance of adequately training NTSB investigators to ensure that they ask the right questions during an investigation.

Critics of the party process also claim that parties use NTSB investigations to point the "finger of blame" at each other in an effort to deflect future liability (Fredrick, 1996).³⁸ Divisiveness along party lines is considered almost inevitable, particularly in major investigations, but it corrodes the purpose of the parties' involvement, which is to help the NTSB determine the probable cause of the accident and make safety recommendations to prevent a similar occurrence. "Litigation jockeying" can lengthen investigations by forcing NTSB investigators to seriously consider "purposeful misinformation" provided by one party or another in order to gain advantage in the battle to avoid the assignment of fault and blame.³⁹

Family Representation in Investigations

For family members whose loved ones have perished in an aviation disaster, no issue is more frustrating than their exclusion from the party process. According to family members, conflicts of interest seem to be inherent in a system that allows those who may have been responsible, at least in part, for causing an accident to participate in the investigation.

The National Air Disaster Alliance/Foundation, which claims to represent more than 1,300 family members and survivors, contends that the "independence of the NTSB has been compromised by the airline industry and their dominance and control of the investigation process" (Dunham, December 4, 1998, p. 72). Some family members believe that they should have the right to participate in an accident investigation to the

³⁸The investigation of the crash of American Eagle Flight 4184 reveals precisely the kind of "litigation jockeying" that has thrown the viability of the party process into doubt.

³⁹Confidential interviews with NTSB senior investigators, November-December 1998.

same extent as aviation insurers and defense lawyers, who appear to play such a visible, albeit unauthorized, role in the investigation process.⁴⁰

Families argue that defense lawyers, through their access to party participants, obtain confidential information (such as medical histories and psychological profiles) about family members that is later used against the claimants in civil litigation. The perceived adversarial nature of the investigative process, in which parties are trying to avoid blame, is the foundation for their claim that a place for family representatives in the party system must be defined.

From the plaintiffs' perspective, the importance of NTSB investigative efforts cannot be overemphasized. In individual and group interviews on this subject, lawyers who represent air crash victims repeatedly voiced their frustration.⁴¹ The following comments prepared for public dissemination by a leading plaintiffs' trial attorney convey the general concern (Clifford, April 14, 1999):

[I]t has been the practice of the NTSB to exclude victims and the experts retained by the victims . . . from taking part in the investigation . . . [while] at the same time . . . the NTSB almost always allows the airline and manufacturers of transportation products to [do so]. . . . Thus although the NTSB is defined as an independent agency, it allows the input and hands-on aid of the defendants into its investigation of transportation accidents but denies the victims from having any input into the investigation and hands-on access to the investigative materials until the investigation is completed. The NTSB has . . . assert[ed] that the Board's factual report[s] of an air accident investigation, which contain many of the facts collected in the investigation, are readily available upon request in the agency's public docket. . . . [H]owever . . . representatives for the airline and aircraft manufacturing defendants are still allowed to participate in the investigation as it goes on while the plaintiffs have to wait and wait for months at a time to gain access to the "fruits of the investigation." Thus the defendants have a significant head start in preparing their defense to these cases. This puts the victims at a severe disadvantage from the very beginning. . . . For the victims, the NTSB investigation

⁴⁰Meeting with 15 family representatives, Washington, D.C., December 1998.

⁴¹Confidential interviews with plaintiffs' attorneys, September 1998 to April 1999.

often turns into an extended ordeal in which these victims' efforts to discover the cause of the accident are thwarted by the consistent denial of the NTSB to allow representatives of the victims--their expert witnesses--from being present during the initial investigation and any subsequent testing of component parts. This leads to an immediate suspicion among the victims as to the credibility of the investigation.

Families and plaintiffs' attorneys also complain that the NTSB's long delays in completing recent high-profile investigations, such as USAir Flight 427 and TWA Flight 800, are unnecessarily prolonging the resolution of lawsuits and claims. Courts are ordering the postponement of discovery and in some cases declining to set trial dates until the NTSB investigation is completed.⁴²

Unresolved investigations have resulted in the collapse of funding agreements, preventing insurers from settling compensation claims. This prolongation of litigation imposes a painful burden on surviving families struggling to overcome their losses and to regain personal and financial stability.

Family members (and plaintiff lawyers on their behalf) want to participate in the NTSB party system and assume a role equal to the parties whose negligence or misdeeds may have caused the accident. They argue this would make investigations more open and honest, counterbalancing the conflicts of interest that, from their point of view, characterize the party process. They contend that the families' basic constitutional rights of due process are being violated when they are denied access to important information about the progress of the investigation (Dunham, 1998).⁴³ Family advocates assert that they have a

⁴²The litigation of claims in cases involving the crash of TWA Flight 800 and USAir Flight 427 have been significantly delayed pending the completion of the respective NTSB investigations. In the case of USAir Flight 427, the NTSB investigation took more than four years to complete. The final hearing on the NTSB Accident Report took place on March 23, 1999, but the federal district court in the Western District of Pennsylvania, where several cases are pending, indicated that no trial dates would be set until nine months following the issuance of the NTSB's Final Report, which finally occurred in August 1999. The release of the NTSB's final report on TWA Flight 800 was expected no sooner than June 2000, almost four years after the accident occurred.

⁴³However, in the case of *Graham v. Teledyne-Continental Motors*, 805 F.2d 1386 (9th Cir. 1986), the court rejected arguments that denying the pilot's estate access to the NTSB engine teardown resulted in the

special interest in finding out what caused the accident and preventing it from happening again, and they argue that, in the interests of fairness and justice, family members or their representatives should be given formal status in the inquiry.⁴⁴

Despite the emotional appeal of families' arguments, there are well-grounded objections to their direct or indirect participation in the party process. The central objection is the potential dilution of the goal of accomplishing an unbiased technical examination of an accident's cause. The NTSB, and in turn the IIC, is charged with selecting professionals from government agencies, companies, and associations whose special skills or knowledge are likely to contribute to the development of relevant evidence (Miller, Winter 1981).

Private litigants have never been permitted to be parties to NTSB investigations of major commercial air crashes. Airlines, manufacturers, and even NTSB staff argue forcefully that family members and plaintiff lawyers have no inherent special expertise that could help to solve the accident. Instead, staffers complain about having to "chase down" unsubstantiated causation theories offered by families and other outsiders, dissipating scarce budgetary and human resources. Furthermore, selecting family representatives to serve in a party capacity would be difficult. Even within family support groups, differing opinions among many families on key matters concerning a crash have led to feuds and ill will.

In addition, many families choose not to be part of an organized group. Designating one or more lawyers to serve as party representatives could lead to objectionable (and illegal) solicitation of clients in order to secure such a preferred position.

kind of deprivation of evidence that would constitute a denial of due process with respect to related civil litigation. The court noted that if the appellant's claim were sustained on constitutional grounds that it would be difficult to exclude others from the investigation, a problem that would be "infinitely multiplied" in a crash involving a major airliner.

⁴⁴Meeting with 15 family representatives, Washington, D.C., December, 1998.

Proposals to Extend the Parties' Role to the Analysis Phase of the Investigation

When the fact-finding portion of an investigation is completed, the IIC and NTSB technical staff begin the task of analysis and production of the Final Report--the document that is submitted for approval to the five Board members.

Parties are allowed and, in fact, encouraged to make written submissions to the NTSB of findings, conclusions, probable cause, and recommendations that they believe should be drawn from the factual record; such party submissions become part of the public docket of the investigation. These written submissions are the formal tool by which the parties participate in the Safety Board's analytical process (Benzon, March 29, 1994, pp. 64-65). No statute or rule specifically prohibits more direct party involvement in this process; rather, the Safety Board has historically assumed that direct party participation in this phase of the process could jeopardize the independence of the Safety Board's final product.

Many of the companies and organizations frequently named as parties in major investigations have sought to have more input into the NTSB's Final Report, including the written analysis, probable cause findings, and safety recommendations. ALPA and Boeing, among others, contend that the Safety Board's rules and investigative procedures should be revised to expand the role of parties during the analysis portion of the investigation (Hagy, March 29, 1994, p. 169).⁴⁵ From their point of view, excluding the parties from this critical phase contradicts the very purpose of the party system--to enhance the technical competency of the investigative effort.

Parties cite numerous instances in which an NTSB Final Report has contained (in their view) erroneous findings and conclusions, often contrary to the findings contained in the initial Working Group factual reports. The parties attribute such "mistakes" to the perceived inadequacies of NTSB staff working without the benefit of party participation. In addition, party participants are seeking the

⁴⁵Also, confidential interviews with Boeing senior executives, December 1998 and January 1999.

opportunity to review and comment on the draft Final Report and proposed recommendations prior to the completion of the investigation. They argue that expanding their participation in the NTSB's work would create a better product, enhance acceptance of safety recommendations, and reduce the number of petitions for reconsideration that add to the NTSB's workload (Broderick, 1998).⁴⁶

Proponents of granting parties a participatory role in the analysis phase base their position on two suppositions: (1) that the party system is the only way for the NTSB to acquire the technical expertise it needs to accurately determine the cause of a major aviation accident and (2) that parties are sufficiently free of bias and conflict of interest to eliminate the risks inherent in extending their influence. RAND's research does not support either of these suppositions. Rather, it points toward a need to enhance the party system in certain situations. As Chapter 6 discusses, many resources that are free of the self-interest that stems from the parties' conflicting roles are available outside the party system to supplement the NTSB's technical ability and expertise.

Whereas the mission of the NTSB is narrowly defined to determine probable cause and prevent future accidents, parties are inevitably concerned with broad issues of corporate responsibility and liability. In trying to avoid fault, or the perception of fault, those participating in NTSB investigations must navigate a complex matrix of overlapping responsibilities.⁴⁷ Allowing the parties to directly influence the final process by which the NTSB reaches its conclusions and recommendations is likely to exacerbate these conflicts.

⁴⁶Also, confidential interviews with Boeing Commercial Aircraft senior executives, December 1998; confidential interviews with Airbus senior executives, Toulouse, France, September 1998.

⁴⁷The frequency with which information about investigations is leaked to the media is symptomatic of conflicting party roles. NTSB officials express real concern that some interested parties, if granted access to the later analytical stages of the investigation, would leak sensitive information, inviting pressure from families, politicians, business interests, and others for the NTSB to alter its proposed conclusions and recommendations.

Although its role should not be expanded beyond fact-finding, the party system can and should remain a key component of the NTSB investigation process. Parties provide unique and essential information about aircraft design and manufacture or airline operations. However, as with any complex system, the party process has its own "failure mode." Recent major aviation accident investigations reveal that in some circumstances the effectiveness and integrity of the party system is limited. Investigations such as those surrounding the crash of TWA Flight 800, USAir Flight 427, and American Eagle Flight 4184, in which the central stakeholders in the accidents jockey with each other and the NTSB to avoid responsibility and blame, highlight limitations of the party process.

Regardless of the number of deaths involved (which ranged from 68 to 227), each of these accident investigations shared the following five characteristics:

- Fleet design or operations were implicated in the accident.
- Each involved complex systems failures.
- Each generated costly product liability claims related to design defects.
- Sales, market share, and the competitive position of one or more parties were significantly threatened.
- The resulting NTSB investigations lasted two or more years.

As discussed in Chapter 3, these traits are characteristic of the kinds of accidents the NTSB will likely be called upon to investigate with greater frequency in the future. The shortcomings (and in some instances outright failure) of the party system in such cases underscore the urgent need to expand the resources available to the NTSB.

Enhancing the Party Process

Although the evidence is anecdotal, it is possible that the party system has contributed to a widespread perception that the NTSB has been "politicized." This term has different meanings among stakeholders, but the gist is similar: that NTSB investigative outcomes are not entirely derived from the agency's independent technical analyses of the factual circumstances of an accident. The criticism extends to NTSB safety

recommendations. While nobody charges direct political interference with NTSB decisions, critics imply that some special interest groups exercise inordinate influence over NTSB investigations and outcomes.

Some NTSB technical staff members, including a number of senior investigators and division heads, believe the five politically appointed NTSB Board members are prone to overreact to pressures from influential outside interests, such as aircraft manufacturers or family groups, which degrades their confidence in the work of the technical staff. On the other hand, family advocates and plaintiffs' attorneys believe that the technical staff, lacking adequate resources and expertise, is vulnerable to influence, and to even deceit and misinformation, from the parties (manufacturers, airlines, and ALPA, in particular). Meanwhile, stakeholders in the aviation industry assert that the NTSB Board members, driven by the media, public opinion, and political ambition, lean toward "politically correct" decisions with respect to findings of probable cause, even if those findings are contrary to the facts uncovered in the investigation.

It is clear is that the safety of the flying public depends to a significant degree on the ability of NTSB investigators to independently ascertain the cause of major aviation accidents and on the willingness of the NTSB Board members to take all necessary actions dictated by those findings. To the extent that the party system impinges on the NTSB's ability to carry out its mission, or its perceived ability to do so, its role should be constrained and the NTSB's independent capabilities should be enhanced.

The left-hand side of Figure 4.2 presents a diagram of the existing party process model, with party participants providing most of the outside technical expertise available to NTSB investigators. Currently, the NTSB use of experts outside the party process is limited; party members are usually consulted prior to the use of outside experts, and they are also given an opportunity to review and revise work assignments.

The diagram on the right-hand side of Figure 4.2 presents a notional view of a new party process model, with expanded use of other

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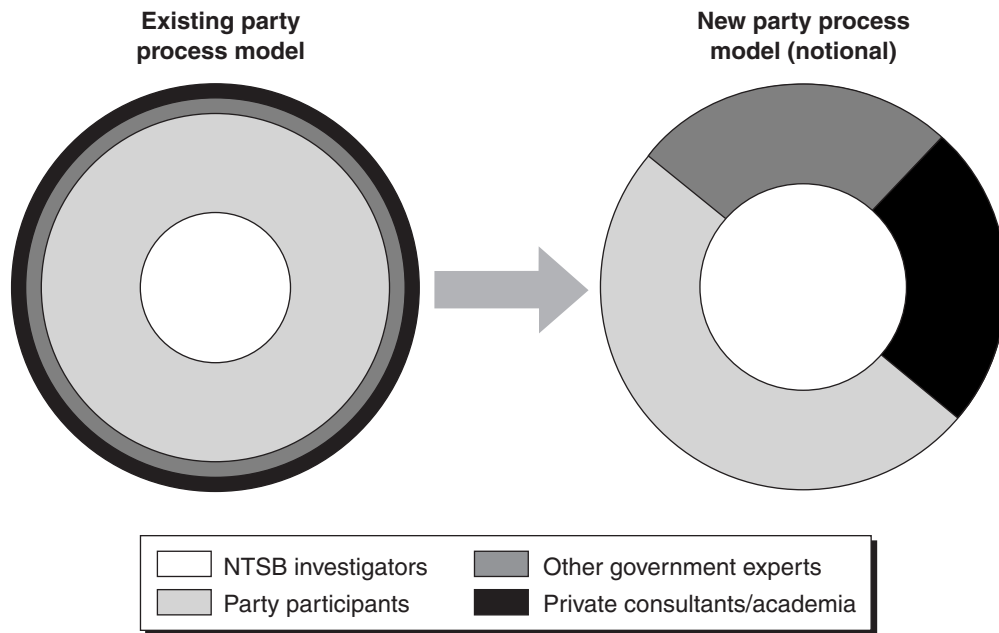


Figure 4.2--Existing and Notional Party Process Models

government experts, private consultants, and scholars. Here the role of outside experts is more expansive. In this notional model, the NTSB would access experts it deems necessary to conduct certain tests, analyses, and reviews without first consulting party members.

The goal of enhancing the party process should be to assure that the NTSB can access nationally and internationally recognized experts and expert teams when senior managers see the need for their assistance. Chapter 6 integrates this concept of an enhanced party process with the concept of a revised investigative model based on multidisciplinary teams. The use of "knowledge management" to speed access to expertise is also discussed in Chapter 6.

DETERMINING PROBABLE CAUSE

By statute, the Safety Board's fundamental objective is to investigate accidents and "to establish the facts, circumstances, and cause or probable cause" thereof, exclusively for the purpose of

preventing similar occurrences.⁴⁸ As straightforward as this objective may seem, the determination of probable cause has proven to involve a complicated entanglement of science and law, defying clear definition or direction.

A genuine confusion exists at times, both within the NTSB and in the aviation community as a whole, as to whether the Safety Board is to determine "what happened" or "why it happened" and whether there is a difference between the two levels of inquiry. Recent accident investigations have demonstrated how difficult it is for the NTSB to remain focused on its narrowly defined mission amid a legal environment in which the fundamental goal is to assign fault and blame, all of which raises the following questions:

- Is a safety-oriented investigation as demanding about uncovering the facts as a judge and jury, or the jury process (Miller, Winter 1981, pp. 266-268)?
- Is the accident investigation process, characterized by rigorous technical analysis and careful documentation, different from the kind of adversarial fact-finding process that is fundamental to the civil justice system?
- What have been the consequences of imposing terms relating to legal proof on an investigative process that is managed by engineers and scientists?

In order to understand what "probable cause" is supposed to mean in the accident investigation context, it is worthwhile to examine the term's origin. The renowned evidence scholar, Professor W. H. Wigmore, first sought to define the term "probable cause" as it related to the duties of early accident investigation agencies (Miller, Winter 1981, pp. 267-268). The term has been applied in various contexts and is explicitly mentioned in the Fourth Amendment to the U.S. Constitution: "No warrants shall issue, but upon *probable cause*" [emphasis added]. Here the term refers to the quantum of evidence necessary for a reasonable person to believe that an accused individual had committed a crime.

⁴⁸49 U.S.C. 1131(a).

When removed from the arena of criminal law, the term "probable cause" can be used to describe the level of inquiry appropriate to a safety investigation--conditions or events that *most likely* or *probably* caused the accident to occur, although historically the term has little to do with cause and effect of matters related to technology. The term "probable cause" may have been employed to differentiate the work findings of accident investigators from the findings of lawyers in litigation (Miller, Winter 1981). However, this important distinction seems lost on many of today's stakeholders, including the news media, which when failing to distinguish between the safety-related purpose of an NTSB investigation and the objectives of civil litigation simply view the NTSB's determination of probable cause as the means to assign fault and blame (Quinn, Fall 1995).

According to the statutes and rules that govern the NTSB, a finding of "probable cause" is required to solve an accident and support the issuance of safety recommendations. Despite the confusion that has surrounded this term almost since its inception, no more specific definition has emerged, either through regulatory or judicial interpretation. The NTSB's *Investigator's Manual* defines "probable cause" as the condition(s) and/or event(s) or the collective sequence of conditions and/or events that "most probably caused the accident to occur." The *Manual* goes on to explain that had the condition or event been prevented, the accident would not have occurred.

Efforts to refine the definition of probable cause to reflect the more complex nature of aviation accident investigations, as well as to minimize confusion with the objectives of civil litigation, have repeatedly been rebuffed at the highest levels of the NTSB (Miller, Winter 1981).⁴⁹ At the same time, courts have not addressed the interpretation of probable cause when considering the procedural

⁴⁹Miller discusses attempts to revise the "probable cause" terminology in the early history of the NTSB. The reluctance of the Safety Board to revamp the agency's probable cause mandate in the context of more recent criticism is chronicled later in this chapter.

questions related to legal challenges to the NTSB's authority or discretionary decisionmaking.⁵⁰

Within the legal system, various measures of proof are employed to denote the level of certainty required for the imposition of criminal or civil liability. Evidence "beyond a reasonable doubt," the highest standard, is required for criminal conviction. Many jurisdictions have adopted the somewhat lower measure of "clear and convincing" evidence to support the award of punitive damages in civil cases. A "preponderance of the evidence," loosely figured at 51 percent of certainty, is all that is generally required to support a finding of negligence or other civil liability and the award of compensatory damages.

Instead of employing a similar determination standard for the NTSB's findings, the term "probable" seems to take on different meanings depending on the severity of the accident and the public visibility of the agency's proceedings. The "hotter" the investigation, the more certainty is demanded within the NTSB and by the parties and other stakeholders. At times, "probable cause" is equated with the legal standards of "clear and convincing" evidence or proof "beyond a reasonable doubt."

Attempting to chase a moving standard impacts the NTSB's ability to complete its investigations in a timely fashion. Truth and certainty are always elusive goals, but in the discipline of accident investigation, the search depends on the analysis of highly complex systems, the testing of damaged components, the replication of unusual flight conditions, and recovery or even reconstruction of wreckage. In the face

⁵⁰The absence of judicial reflection on the meaning of "probable cause" in the context of aviation (or any other mode of transportation) accident investigation is attributable to two factors. First, NTSB findings of probable cause and related safety recommendations are not subject to review under the Administrative Procedures Act, thus eliminating the opportunity for judicial review of the agency's actions under the "abuse of discretion" or other standard. Second, most of the litigation challenging NTSB decisionmaking has related to the agency's refusal to designate various individuals or companies as parties to an NTSB investigation or to the permitted use of NTSB materials in civil litigation. In that context, the statutorily defined mission of the NTSB to determine probable cause has not been subject to close examination. See, for example, *Graham v. Teledyne-Continental Motors*, p. 1389, for a general discussion of the NTSB's mission and authorizing statute.

of such daunting tasks, NTSB investigators can lose sight of the fact that their central function is to demonstrate that certain events or conditions "probably" caused the accident.

The adversarial legal process, with the extensive discovery process it affords, is perhaps better suited for developing the quantum of evidence necessary to establish cause, award compensation, and impose sanctions. If the NTSB's only mission is the efficient and expeditious search for the cause of an accident in order to make reasonable safety recommendations, there may be limits as to how far an investigator should go to definitively "prove" how an accident occurred.

The crash of USAir Flight 427 illustrates the danger of interpreting "probable cause" to be the equivalent of conclusive proof. This investigation proved to be one of the most difficult in NTSB history. While mechanical failure of the rudder mechanism was identified early in the investigation as a potential cause of the accident, securing proof of the exact failure mode was complicated by the total destruction of the aircraft, the inability to duplicate the conditions of the accident, and by the limited data about the flight available from an FDR that recorded fewer than a dozen technical parameters.

Nonetheless, Boeing Aircraft, one of the principal parties to the Flight 427 investigation, asserted that the Safety Board must determine "whether there are *conclusive* facts and evidence to support any theory before that theory [a deflection of the rudder] can be identified as the 'probable cause'" [emphasis added].

Citing language used by the NTSB in its report on the investigation of the crash of United Airlines Flight 585 (a 1991 crash of another Boeing 737-200 in Colorado Springs that had similarities to the USAir accident), Boeing contended that evidence of rudder failure had to be "conclusive" and "decisive" (Boeing Commercial Airplane Company, September, 30, 1997, pp. 53-54).⁵¹ Nevertheless, useful and important

⁵¹When the Accident Report on United Airlines Flight 585 was issued, the NTSB was not able to determine the probable cause of the accident. At the time, Flight 585 was the only unsolved mystery in the history of NTSB investigations of major aviation accidents. Although there was some evidence of rudder deflection, there was also evidence of extreme weather conditions. Further research has substantially ruled out

safety recommendations could have been made on the basis of something less than "conclusive" proof as to the precise failure mode of the 737 rudder.⁵² Uncertainty of how much analysis is needed to reach a point of conclusive proof is one of the many dilemmas that contributed to the crisis atmosphere within the NTSB as the investigation of USAir Flight 427 drew to a close.

Pressure to produce a high level of certainty can also come from within the Safety Board itself. Numerous NTSB investigators have bluntly stated that the more controversial the investigation, the higher the level of proof demanded by the NTSB Board members before securing a majority vote for approval of the staff report and related probable cause finding. This scrutiny has been ascribed to the continual and direct lobbying of NTSB Board members by particular stakeholders and parties long after the docketing of the parties' final written submissions.

The investigation of USAir Flight 427 has proven to be a prime example of the heightened proof that Safety Board members may demand before taking action that could be controversial. The NTSB technical staff believed that sufficient evidence existed to conclude that the crash of USAir Flight 427 was caused by the defective rudder design of the Boeing 737, even though the precise failure mode of the Power Control Unit (PCU) servovalve could not be convincingly replicated. Senior NTSB investigators have suggested that certain members of the

such weather phenomena as the cause of the Colorado Springs accident. As part of the Accident Report on USAir Flight 427, the NTSB concluded that the crash of UA Flight 585 was also due to rudder reversal most likely caused by a jam of the main rudder Power Control Unit (PCU) servovalve.

⁵²The safety issues addressed in the Accident Report on USAir Flight 427 cite Boeing 737 rudder malfunctions, including rudder reversals, the adequacy of the 737 rudder design system, unusual attitude training for air carrier pilots, and FDR parameters. As a result of the USAir Flight 427 accident, the NTSB issued a total of 17 safety recommendations to the FAA in October 1996 and February 1997 regarding operation of the Boeing 737 rudder system and unusual attitude recovery procedures. In addition, as a result of the USAir Flight 427 and UA Flight 585 accidents, the Safety Board issued three recommendations to the FAA in February 1995 regarding the need to increase the number of FDR parameters. An additional 10 recommendations were issued on the date of the Board's final hearing on the USAir Flight 427 Accident Report (National Transportation Board, March 24, 1999).

Safety Board demanded proof "beyond a reasonable doubt" that the rudder, not pilot error, caused this accident, as well as a definitive demonstration of the failure mode of the rudder mechanism. In confidential interviews, senior NTSB staff suggested that the investigation could have been completed in half the time if it were not for the demand by the parties and some Safety Board members for absolute proof of a rudder deflection.

Figure 4.3 illustrates the relationship between the characteristics of an investigation and the likely influence of the NTSB's recommendations. A review of many of the Safety Board's most recent major aviation accident investigations reveals a number of additional factors that tend to "raise the temperature" with respect to the exactitude of the probable cause statement. These factors include the following:

- multiple accidents involving a particular type of aircraft
- a history of incidents similar to the circumstances of the suspected cause of the accident
- a large number of deaths

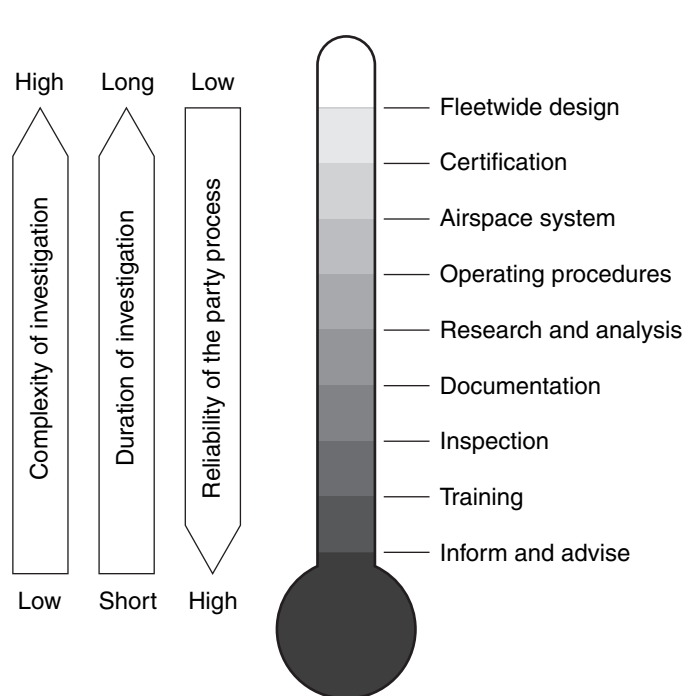


Figure 4.3--The Investigative Scale

- a large number of parties
- a first-time accident suggesting a previously unknown operational failure
- heightened media interest
- intense family involvement
- political pressure from Congress and/or the White House.

As these factors mount, so do the demands on the NTSB to "get it right." A finding of probable cause so obviously suggests blame and fault that, rightly or wrongly, it sets off a series of complicated events that exceed the boundaries of an NTSB investigation. In this environment, the NTSB must conform to the standard of proof appropriate to the mission of the agency--that is, issue a determination of what "probably" caused the accident.

The Primacy of the Probable Cause Finding

Arguably, the most important outcome of an investigation is the Safety Board's probable cause finding. This statement represents the fulfillment of the NTSB's mission and reflects the cumulative fact-finding and analytical work of its technical staff.

Adoption of the probable cause statement by the five-member Safety Board is viewed as a vote of confidence in the work of the investigators. However, a finding of probable cause has repercussions that are felt well beyond the NTSB. Any person or entity found to have "caused" an accident will be considered by the public and the media to be at fault or responsible for the wrongdoing. In terms of the assignment of fault and blame for a major aviation accident, the NTSB's probable cause finding is "the whole ballgame."⁵³

A finding of probable cause may set off a chain reaction of regulatory activity. Safety recommendations based on the finding are forwarded to the FAA, which must provide a formal written response to

⁵³ Almost every individual interviewed by RAND, no matter his or her association or relationship to the accident investigation process, used this term. The universal use of this wording was remarkable, but also serves to underscore the significance with which the NTSB process is regarded by all the various stakeholders affected by the NTSB's investigation of major aviation accidents.

the NTSB within 90 days. The response must indicate whether the FAA intends to adopt the recommendations, in whole or in part, and if it does not intend to do so, it must state the reason why.⁵⁴

Among its options, the FAA may consider incorporating the safety recommendations into Federal Aviation Regulations (FARs), which cover every facet of civil aviation. Such regulatory action is a complex process, requiring the FAA to evaluate the economic impact of the NTSB recommendations, including the costs and benefits of implementation. Public and private hearings regarding the proposed action may be held, often with the participation of the Aviation Rulemaking Advisory Committee (ARAC), an industry advisory group established by the FAA to assist in the regulatory process. The Administrative Procedures Act requires that every federal rule first be issued as a "proposed rule" and that time be provided for public review and comment ("How an FAA Rule Is Changed," April 1998).

Alternatively, the FAA may issue airworthiness directives, service bulletins, or advisory circulars that require the recipient to order repairs, maintenance, or inspections of aircraft; change airline operations; alter flight rules or airport operations; or take other various actions. Implementing such operational changes may have an adverse effect on an airline's profits or may even damage the competitive position of an aircraft manufacturer or airline.⁵⁵

NTSB safety recommendations can also put at risk the continued certification of an aircraft or a component part, and may even jeopardize the right of an airline to carry passengers. Certification becomes an issue when the cause of an accident is attributed to faulty design or manufacture, calling into question the safety of an entire fleet of airplanes, not just the particular plane involved in the accident. The withdrawal of certification requires action by the FAA,

⁵⁴49 U.S.C. 1135(a).

⁵⁵Airbus has successfully touted the relatively low number of air service directives that have been issued against the Airbus 319 and Airbus 320 compared with the Boeing 737 as a means of increasing sales and market share in the "single aisle" aircraft category (confidential interview with senior aviation industry executive, March 1999).

even though the NTSB's finding of probable cause may point directly to improper certification by the FAA in the first place.

For an aircraft manufacturer, the consequences of decertification are incalculable, jeopardizing future sales and inevitably requiring extensive modifications before the aircraft can be brought back into service.⁵⁶ Although a safety recommendation of this magnitude carries dramatic consequences, the NTSB has pointed to defective design and the FAA's failure to properly certify an airplane as the probable cause of several recent major accidents.⁵⁷

It is important to note that the applicable FARs, as well as the rules contained in flight and air traffic control manuals, airworthiness directives, and even advisory circulars, are admissible in civil litigation arising out of airplane accidents. They are viewed by the courts as "strong, impartial, and authoritative evidence of the proper standard of care under the circumstances" (Kreindler, 1998, pp. 10, 22-23).

In many jurisdictions, the violation of air safety regulations constitutes negligence *per se*.⁵⁸ As a consequence, safety recommendations issued by the NTSB often amount to nothing short of the

⁵⁶Confidential interviews with senior executives of Airbus Industrie, Toulouse, France, September 1998, regarding the impact of the NTSB's investigation of the crash of American Eagle Flight 4184 and the subsequent warning that the the ATR-72 was unsafe to fly in certain icing conditions.

⁵⁷Defective design and improper certification were deemed to be the probable causes of the crash of American Eagle Flight 4184 (improper wing design and deicing equipment of the ATR-72) and Comair Flight 3272 (Embraer 120). The NTSB did not specifically state that improper design of the Boeing 737 rudder and related PCU was the cause of the crash of USAir Flight 427 or United Airlines Flight 585.

⁵⁸For a discussion of the applicable principles governing negligence *per se*, see Restatement (Second) of Torts §288B(1) (1965): "The unexcused violation of a legislative enactment or an administrative regulation which is adopted by the court as defining the standard of conduct of a reasonable man, is negligence in itself"; §286: "The court may adopt as the standard of conduct of a reasonable man the requirements of a legislative enactment or an administrative regulation. . . ."; and §§285-288C, Section 285, comment b, states that although the doctrine applies to administrative regulations that define and establish a standard of conduct, "cases will be comparatively infrequent in which administrative regulations can be construed to have such an effect."

standard of care required of *all* airline operators, manufacturers, service providers, or other stakeholders engaged in commercial aviation.

Beyond the regulatory impact, a finding of probable cause by the NTSB is very significant for the civil litigation associated with a major commercial aviation accident. Stakeholders on all sides describe the importance of the NTSB Blue Book and the probable cause determination in the same terms: These findings provide the "roadmap to liability." Claimants and defendants wait many months, and sometimes several years, for the NTSB to articulate the probable cause of the accident. After the NTSB investigation is completed, the restraints that have been placed on court proceedings are removed and the claimants and their lawyers move quickly to pursue the theories of liability that are outlined in the NTSB report.

It must be noted again that determination of potential liability is *not* the NTSB's mission. NTSB investigative procedures are designed to develop information for the purpose of accident prevention, and *not* to find information to assess blame. Although the rules explicitly state that NTSB investigations are not conducted for the purpose of determining the rights or liabilities of any person, the findings and conclusions of the NTSB are nevertheless such a powerful and persuasive statement of what took place to cause the accident that conclusions about liability are inevitable.

Furthermore, public access is guaranteed, with a few exceptions, to all communications, documents, or reports received by the NTSB. As was described earlier in this chapter, most of the factual information and analysis developed by the Safety Board, other than the probable cause statement, is usually admissible as evidence despite rules designed to isolate the NTSB from the litigation process. Although plaintiffs' attorneys must independently establish the fundamental elements of their case--negligence and causation--through their own discovery and fact-finding, the NTSB Accident Report inevitably points the way.

The NTSB report is not, however, a complete substitute for traditional methods of discovery and the proper development of evidence. In fact, litigation subsequent to several recent major accidents

uncovered significant causal factors overlooked by the NTSB. Plaintiffs' lawyers must provide the basis for punitive damages by showing that the defendant demonstrated gross negligence or flagrant, unconscionable conduct.⁵⁹ The NTSB's only task is to uncover the defect or faulty procedure that caused the accident; assessing the defendant's degree of culpability for wrongdoing is the task of the civil justice system.

While the NTSB report might enlighten claimants (and their lawyers) who have been barred from participating in the investigation, the finding of probable cause may overlook other contributory factors that prove to be as persuasive, if not more, in establishing liability before a judge and jury.⁶⁰ When the NTSB holds a governmental entity (such as the FAA) responsible for an accident, claimants will seek evidence of culpable conduct by other potential defendants, thus allowing them to circumvent the federal government's bar against the award of punitive damages.

⁵⁹In the case of air crashes occurring outside the United States, claimants must be able to demonstrate that the air carrier engaged in "willful misconduct" to escape the limits on recovery imposed by the Warsaw Convention, or prove that a party other than the airline, such as the manufacturer or maintenance service, was at fault. This will likely be the case with respect to the crash of TWA Flight 800, in which TWA's potential liability will be limited to approximately \$140,000 per claimant (per current drawing rights under the Warsaw Convention, as amended), unless willful misconduct on the part of TWA can be proven.

⁶⁰In the litigation resulting from the crash of American Eagle Flight 4184 (*in re Air Crash Disaster Near Roselawn, Indiana*, on October 31, 1994, N.D.IL), plaintiffs counsel were prepared to present extensive evidence establishing the negligence of the American Eagle pilots for failing to maintain a sterile cockpit during the "hold" imposed by air traffic control prior to clearing the plane for landing at Chicago O'Hare International Airport. It was during this period that the icing conditions that precipitated the crash were experienced. The NTSB determined that the probable cause of the Roselawn crash was (1) the failure of the manufacturer to disclose to operators information previously known about the effects of freezing precipitation on the stability and control characteristics of the aircraft, and (2) the failure of the French Directorate General for Civil Aviation and the FAA to take corrective action to assure the airworthiness of the ATR-72 in icing conditions. Misconduct by the flight crew was not part of the Board's probable cause determination. Although the litigation was settled before trial, the issue of flight crew misconduct is the basis for ATR's motion for reconsideration of the NTSB's findings and conclusions currently pending before the Board.

The NTSB's finding of probable cause sets off a chain reaction of events in the litigation arena. Among other things, defendants may admit to liability rather than contest or retry the issues of fault in court. The risk of, and costs associated with, extensive discovery, a lengthy trial, the possibility of an adverse jury verdict, the potential award of punitive damages, and the attendant adverse publicity may compel defendants to concede liability and work toward the settlement of individual compensation claims. Any parties to the investigation who are also defendants would know just how strong a case might be made against them in the litigation setting.

From the perspective of insurers, the NTSB's findings may call for an adjustment of the funding agreement that has financed claimant settlements up to that time. This is especially likely if more than one insurer has been involved with the accident. For example, if one insurance company insured the air carrier and another insured the airplane manufacturer, the release of NTSB findings may prompt one party or another to acknowledge liability and the insurers to alter the funding agreement accordingly. Although such an adjustment might not immediately impact the process of settling compensation claims with plaintiffs and their lawyers, a dispute among the parties and their insurers about the validity of the NTSB probable cause findings could result in subsequent litigation of the respective liabilities of the parties to the funding agreement.

Accepting responsibility for causing a major aviation accident, or for appearing to have been the cause, can be imposed through other forms than just civil litigation. If anything, the "court of public opinion" can impose sanctions equal to, if not more onerous than, any jury verdict. A finding of probable cause against an airline or manufacturer can result in significant loss of business and damage to a company's reputation. News of such important action can have an impact on a traveler's choice of airline, and it can instantly affect stock prices and corporate profits. If an aircraft or airline is labeled unsafe, sales and market share could plummet.

In countries other than the United States, where wrongful conduct is more commonly punished and deterred by criminal sanction rather than

by the award of civil damages, a finding of probable cause can translate into potential corporate criminal liability (Wald, July 14, 1999).⁶¹

A stakeholder found to be at fault may have to bear the cost of uninsured expenses, such as outlays for a lengthy NTSB investigation (including tests required by the NTSB) or a punitive damage award, which could be many millions of dollars. A finding of probable cause pointing toward unsafe operations, poor maintenance practices, or a poorly designed aircraft can raise the cost of liability insurance, significantly cutting into corporate profits or causing airline ticket prices to rise. Ultimately, the loss of public confidence in the safety of the air transportation system could slow industry growth and negatively impact the domestic and international economies.

Restructuring the Probable Cause Finding

Given the controversy generated by a finding of probable cause, it is not surprising that stakeholders have suggested reforms to the process. In fact, eagerness to reform or to at least refine the NTSB's statutory mandate to determine probable cause is almost as old as the NTSB itself (Miller, Winter 1981, pp. 289-291; Miller, Spring 1998). For example, some stakeholders have suggested that different terminology would not lend itself so easily to sound bites and simplified labels. Words such as "findings," "significant factors," or "causal factors" might remove the contentiousness surrounding "probable cause" without detracting from the significance of the process from a safety standpoint (Lederer, March 1992).⁶²

⁶¹The Boeing Company has already been indicted in France as a result of the crash of TWA Flight 800, even though, as of this writing, the NTSB has not concluded its investigation. On July 13, 1999, SabreTech, the aviation maintenance company responsible for the improper handling of oxygen generators that exploded and caused the crash of ValuJet Flight 592, was indicted by Florida authorities on 110 counts of third-degree murder and manslaughter. A federal grand jury also indicted the company and three of its employees for improper handling of hazardous materials. These were the first criminal charges brought in an airline accident in the United States.

⁶²The same point was made at a RAND roundtable of government aviation officials in Washington, D.C., in October 1998.

Stakeholders have proposed a variety of other reforms as well, ranging from eliminating the NTSB's responsibility to determine probable cause to suggesting that the NTSB merely list causal factors in alphabetical or chronological order. Semantics aside, aviation safety specialists contend that the emphasis on a single "cause" is misplaced, leading to inadequate understanding of the many causal factors that come together to bring about a particular accident (Snowdon and Johnson, 1998).⁶³

Accident prevention is cited as the most important reason for *expanding* the NTSB's findings. Those seeking useful information to prevent future accidents roundly criticize the finger-pointing that accompanies the NTSB's determination of probable cause. This criticism is directed to the Safety Board's process of rendering the final decision and to the actual label of "probable cause" itself. Analysts of complex systems contend that major aviation accidents are not the result of a single failure of one component, but are the product of complex interactions among people, machines, and the environment that must be understood by both investigators and stakeholders (Luxhoj, Arendt, and Horton, October 15, 1997).

The NTSB's emphasis on probable cause has been criticized as being overly accusatory in many cases, oftentimes implicating the performance of the flight crew as the only cause of an accident. The ALPA has been particularly critical of the NTSB approach, charging that so long as the probable cause is pilot error, the inducement to invest in system improvements will be limited (Steenblik, June 1992). ALPA claims that issues such as training, airline management, facilities, weather, air traffic control, or crew resource management frequently receive little, if any, attention from the NTSB.

In accordance with NTSB procedures, probable cause is summarized at the beginning of the Final Report, but contributory causes are relegated to accompanying volumes of technical material. Other investigative

⁶³This article by Snowdon and Johnson notes how important it is for aircraft designers to be aware of alternative hypotheses for aircraft failures and the entire set of contextual factors that surround major failures.

bodies treat this information much differently. For example, the Transportation Safety Board of Canada (TSB) is required to render "cause-related findings," but is not required to make a definitive probable cause(s) determination. The TSB is, however, permitted to make findings on unrelated matters that identify safety deficiencies. The U.S. Air Force applies the "all cause" concept, identifying all factors that "substantially contributed to or caused" a military aircraft accident, unless there is "clear and convincing" evidence sufficient to support a single cause. In the Air Force scheme, a substantially contributing or causal factor is one that played an important role, either directly or indirectly, in the sequence of events that led to the accident. Any conclusion about such substantially contributing or causal factors must be based on "substantial evidence," defined as "more than a trace of evidence," such that a reasonable person would accept as adequate to support a conclusion.

Table 4.1 contains descriptions of the types of causal determinations made by various aviation accident investigative agencies. Definitions of cause determinants can be found in the accident investigation manuals of the respective agencies.

The NTSB has historically resisted the notion of altering its statutory mandate to determine probable cause. In 1994, as part of the Safety Board's Aviation Accident Symposium, several party stakeholders recommended that the Safety Board change its approach to probable cause. The Safety Board officially rejected those industry recommendations, stating that a chronological listing of factors or causes would "diminish the impact of key occurrences in the accident, therefore reduc[ing] the safety potential of the investigation" (National Transportation Safety Board, March 29, 1994b, p. 9). The NTSB instead agreed to consider the wording of the probable cause statement on a case-by-case basis. NTSB Board members and senior staff have also expressed concern that eliminating the probable cause determination would undermine the foundation for related safety recommendations.⁶⁴

⁶⁴Confidential interviews with senior NTSB staff and Board members, October-November 1998.

Table 4.1
Cause-Related Determinations by Various Investigative Agencies

Investigative Body	Determination of Causation
NTSB	Probable cause
NASA	Dominant root cause
U.S. Air Force	All causes/probable cause only if "clear and convincing" evidence
International Civil Aviation Organization (ICAO)	All causes, including secondary causes
Bureau Enquetes-Accidents (BEA), France	All causes
Transportation Safety Board (TSB), Canada	Cause-related findings/identify safety deficiencies
Bureau of Air Safety Investigation (BASI), Australia	All causes

The factual findings and analytical conclusions of the NTSB are authoritative statements, and the statement of probable cause carries considerable weight in the aviation community. Because the NTSB lacks regulatory or enforcement authority, the influential and highly public pronouncement of probable cause is one way for the agency to play a central role in aviation safety. In that context, probable cause serves to carry out important policy goals and should be retained. However, identifying all causal factors material to the cause of an accident would improve the quality of the NTSB's output. The probable cause statement should be more than a simplistic conclusion; it should serve as a signpost guiding future aviation safety goals.

Adoption of a more sophisticated approach to the formulation of probable cause would provide more consistency and substance to the end product of the NTSB investigative process.

CHAPTER 5
STAFFING, WORKLOAD, AND TRAINING AT THE NTSB

The NTSB is a small agency with a big mission. The projected growth in air traffic and increasing diversity in aviation assure the NTSB a continuing important role in aircraft accident investigation. And, while safety initiatives may reduce the quantity of accidents, paradoxically they leave a residual set of accidents that are harder to diagnose, further increasing the technical challenges that NTSB investigators will face.

Because the NTSB's responsibilities extend across all transportation modes, and given the diversity of equipment within each of these modes and the spectrum of possible causes that must be explored for every accident, the Safety Board staff must possess a wide range of expertise. At the same time, to maintain the integrity of the accident investigation process, investigators must have the technical expertise required to elicit necessary facts from technical representatives of the parties to an accident.

Given that the NTSB's staff is limited in number, the quality of its investigators for each specialty area must be exceptionally high. Although the NTSB's aircraft accident investigation staff covers a broad range of specialty areas, each specialty area typically is staffed with comparatively few people, leaving the NTSB vulnerable to staffing shortfalls when key people leave the agency or when accidents occur in clusters. Especially demanding workloads, salary levels that lag behind those for other mid-career industry professionals, and an experienced staff that tends to be older than the average industry employee and therefore closer to retirement age all contribute to the staffing challenges facing the NTSB.

In the course of their work, NTSB investigators must deal with party representatives from airlines or aerospace firms who use and expand their professional skills on a daily basis. On-the-job experience at the NTSB, although useful for sharpening accident investigation skills is, however, not the best means to systematically acquire new

technical skills or refresh old ones. Without periodic training, technical skills can atrophy, putting investigators at a disadvantage in the party system.

Currently, aviation investigators at the NTSB receive far less ongoing training than other members of the aviation community. Ensuring the continued integrity of the accident investigation process requires that NTSB management address these issues.

Staffing, workload, and training policies and processes that impact the size, composition, and skills of the NTSB workforce are becoming increasingly important. In focusing principally on the aviation accident investigation workforce, this chapter characterizes the current staffing posture at the NTSB, discusses factors that could influence that posture, estimates the nature and extent of the current workload, and examines the state of training at the NTSB today.

STAFFING

The NTSB's principal resource is its staff. Attracting and maintaining qualified staff people is critical to the agency's operation. To successfully fulfill the NTSB's mission and remain a standard-bearer for aircraft accident investigation, the Safety Board staff must possess exceptional skills and expertise, combining leadership in relevant technical areas with superior investigative talents and management abilities.

To assess the staffing situation at NTSB, RAND first characterized the workforce by examining its size, depth in key specialty areas, experience levels, and age distribution. We also examined the NTSB's recent experience with attrition and compared its salaries with those of the aerospace industry as a whole. To characterize the NTSB staff, we used internal NTSB records and a questionnaire designed by RAND and administered to the NTSB technical staff during the summer of 1998.¹

¹The questionnaire was sent to every professional employee at the NTSB involved in accident investigation activities, including regional and headquarters technical staff who investigate aircraft and surface transportation accidents, those who track safety recommendation compliance, and personnel who provide research and engineering support to accident investigations. Appendix D describes the administration of

The NTSB's staff, while small, has the breadth of skills needed to cover all transportation modes and diverse equipment types, but it has only limited depth in individual specialty areas. This limited depth leaves the agency vulnerable when an employee possessing critical and unique skills leaves the agency or when accidents occur in clusters, creating multiple simultaneous demands for critical expertise. RAND did not observe any significant actions by the NTSB to compensate for this limited depth, such as strategic alliances with other organizations or cross-training. Nor does the NTSB retain a support service contractor to augment staffing capability in times of heavy workload.

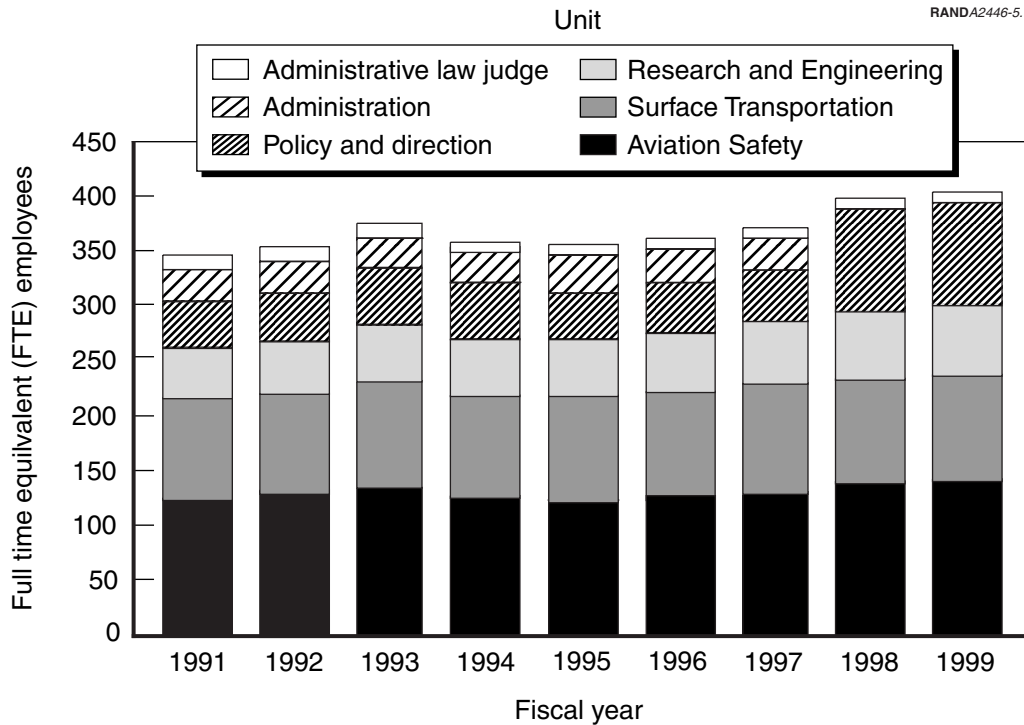
The NTSB typically hires experienced mid-career professionals, many drawn from industry, who must be able to match their expertise with that of party experts in order to maintain the integrity of the party process. A by-product of hiring experienced professionals is a staff with an age distribution that is skewed toward older ages, particularly in the case of the OAS, which has a disproportionate number of staff already at or above age 55.

Replacing retiring employees in a small organization that has limited staffing depth to begin with could pose a substantial hiring challenge for the NTSB in the coming decade. Some features of the NTSB salary structure may serve to further complicate the agency's efforts to attract and retain the experienced staff it needs to perform its investigative function.

Characteristics of the Workforce

Despite its high public profile, the NTSB is a small agency, having just a little over 400 employees. Staffing in the OAS, which encompasses employees at its headquarters and regional and field offices, grew slightly during the 1990s (see Figure 5.1). During that same period, the ORE, which supports accident investigations across transportation modes, had much more growth, with staffing up by about 57 percent.

the survey, the sample, response rates, and selected results. Appendix E provides a copy of the survey questionnaire.



SOURCE: Internal NTSB staffing databases, various years.

Figure 5.1--NTSB Staffing Numbers During the 1990s

As noted earlier, the NTSB has only limited depth in many specialties because of its limited size and the breadth of specialty expertise required for accident investigation. Periodically from 1990 to 1995, the NTSB surveyed its staffing depth in various specialties, often in response to congressional inquiries or as part of its budget submittals. Although the most recent staffing depth survey made available to RAND was for fiscal year 1995, given the moderate growth in NTSB's OAS staff since then, we suspect the current depth is not very different from that shown in Tables 5.1 and 5.2.

To perform aircraft accident investigations, IICs draw on the technical skills of specialists in the OAS and ORE. However, within the specialty areas of the OAS and ORE there are seldom more than one or two staffers expert in each area. In fiscal year 1995, the median number of staff members skilled in any particular aviation specialty in the OAS was just two and in the ORE was only one. In that year, for example, the NTSB listed just one helicopter specialist (at one of the regional

Table 5.1
OAS Staffing Depth in Various Specialties
(Fiscal Year 1995)

Number of Employees ^a	OAS Specialty ^{b, c}
1	Air Safety Investigator (Logistics) Aircraft Maintenance Records Survival Factors: Cabin Safety Survival Factors: Emergency Response <i>Helicopter Specialist</i> <i>Safety Recommendations</i> <i>Accident Data Specialist</i>
2	Meteorology Aircraft Systems: Avionics Aircraft Systems: Hydraulics Aircraft Airworthiness Survival Factors: General Survival Factors: Crashworthiness Safety Recommendations Technical Writer <i>GA Engineering</i>
3	Aircraft Operations Airframe Structure Aircraft Power Plants <i>Accident Analysis</i>
4	Air Traffic Control Human Performance
7	Investigator-In-Charge
49	<i>Air Safety Investigator</i>

SOURCE: Internal NTSB records, FY 1993 to FY 1995.

^aStaff covers Washington headquarters and nine regional locations.

^bMajor investigation specialties are shown in roman type; field investigation specialties are in italics.

^cExcludes supervisory and administrative/clerical specialties.

locations) and one cabin safety expert (at headquarters) (see Table 5.1). At the same time, the ORE had one chemist/fire/explosions expert to cover all transportation accidents investigated by the NTSB (see Table 5.2).²

²With fire and explosions a common occurrence in many transportation accidents, the ORE has since taken steps to add another

Table 5.2
ORE Staffing Depth in Various Specialties
(Fiscal Year 1995)

Number of Employees	ORE Specialty ^a
1	Engineering Applications Engineering Technician Safety Studies: Aviation Safety Studies: Railroad Safety Studies: Highway Safety Studies: Marine Accident Data: Research Methods/Statistics Accident Data: Aviation Analyst Accident Data: Records Management Officer Chemist/Fire/Explosions Technical Writer Writer/Editor Computer Specialist (Applications)
2	Safety Studies: Cross-Modal Accident Data: Accident Data Specialist Accident Data: Records Management Specialist Computer Specialist (Systems)
3	Cockpit Voice Recorder Flight Data Recorder Aircraft Performance Investigator-In-Charge (Hazardous Materials) Metallurgy Materials Analysis

SOURCE: Internal NTSB records, FY 1993 to FY 1995.

^aExcludes supervisory, administrative, and clerical specialties.

With a technical staff that is only one or two persons deep in critical positions, even a single retirement or resignation can materially impact the skills the NTSB can bring to bear in an accident investigation. The NTSB also encounters difficulties when accidents occur in clusters. When this happens, the NTSB typically serves the most immediate need, which can increase the time required to complete other ongoing investigations (Benzon, Summer 1998).

Although the data cannot support definitive conclusions regarding trends, analyses of accident complexity and investigation duration

specialist in the chemist/fire/explosions category. The senior specialist in this category retired after RAND completed its research.

suggest a trend during the 1990s of growing complexity in aviation accidents and longer investigation times. These lengthy investigations work against the NTSB's ultimate aim of finding the cause of an accident and issuing safety recommendations quickly.

Aside from overall trends, RAND noted several specific examples in which limited staffing depth influenced the pace of accident investigations. In one instance, the NTSB, lacking certain in-house expertise, had to delay its investigative work until parties to the investigation completed the results of technical analyses of complex structural dynamics.³

RAND also observed the staffing demands posed by concurrent investigations of complex major accidents, such as the simultaneous investigations of U.S. Air Flight 427 and TWA Flight 800. Although some investigative activity continued on other air carrier accidents, the demands of bringing the U.S. Air Flight 427 accident investigation to a conclusion consumed most of the time of the NTSB headquarters aviation technical staff in the months leading to the final hearing and issuance of a final report.

Strategic alliances outside the party process might be used to augment or extend NTSB expertise at times of especially heavy workloads. Such alliances could also offer NTSB employees more opportunities for professional development. However, the NTSB uses few such formal arrangements.⁴

Some organizations use cross-training to compensate for limited staffing depth. For instance, NASA's Jet Propulsion Laboratory has used generalists to fill skill vacuums when they develop, successfully cross-training small teams to develop and operate interplanetary spacecraft (Muirhead, March 16, 1999). Although migration across organizational boundaries occurs at the NTSB in the course of some staffers' careers, RAND did not observe any extensive use of cross-training.

³This instance involved the crash of Federal Express Flight 14, a MD-11 aircraft that crashed on landing on July 31, 1997, in Newark, N.J. (personal conversation with NTSB IIC for the accident, Summer 1998).

⁴See Chapter 6 of this report for a discussion of the insularity at NTSB and the need for more strategic relationships with the aviation community.

As Table 5.3 shows, the NTSB hires more of its staff from private industry than from any other single source. The Safety Board's ability to continue to attract this sort of employee will depend in part on its salaries relative to private industry.

The NTSB tends to hire very experienced professionals for aircraft accident investigation. Many OAS recruits have 10 years, and in some cases more than 20 years, of experience prior to joining the NTSB (see Figure 5.2). Survey respondents from the OAS (headquarters and regional offices) possessed an average of 11 years of experience at NTSB and 23 years overall.⁵ Headquarters OAS respondents had approximately five years more experience overall than regional OAS respondents, and about two years more time at NTSB.⁶ Respondents from offices representing other transportation modes reported an average of four years less experience than their OAS counterparts.

Table 5.3
Prior Employment of NTSB Employees

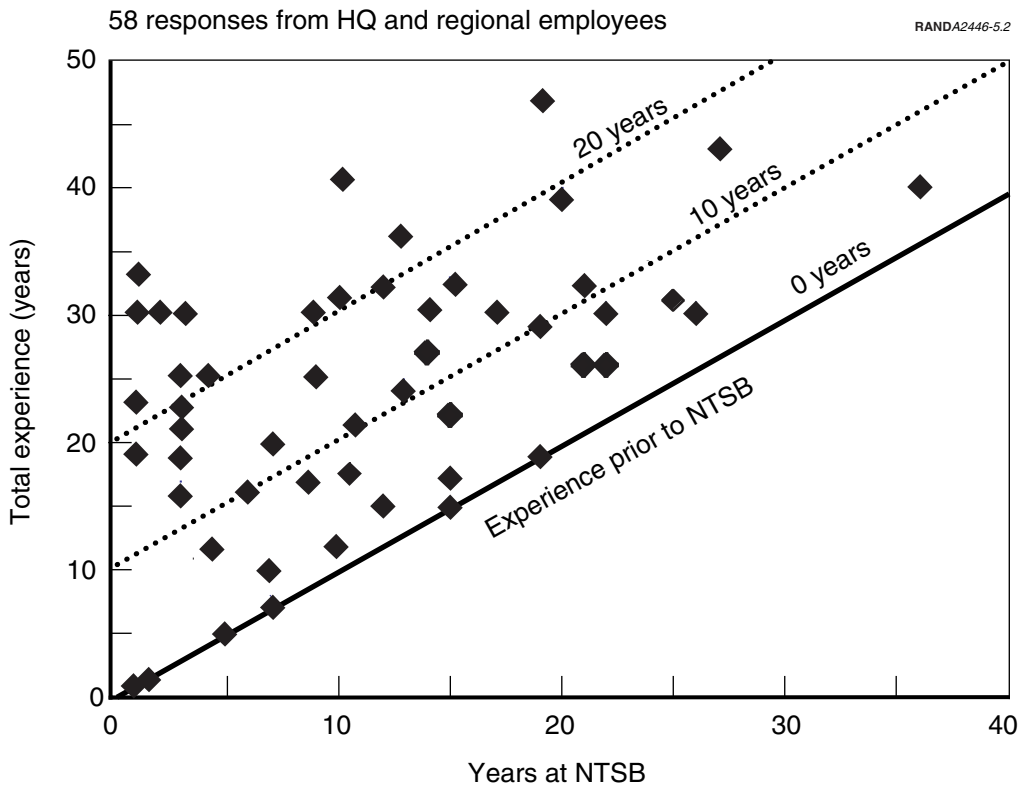
Prior Employment	Percentage of Respondents ^a	
	OAS (all)	All NTSB Respondents
Industry	55	41
Government agency	17	29
Military	17	12
Academia	5	10
Other	5	9

SOURCE: RAND Skills and Experience Questionnaire, Summer 1998.

^a58 respondents from the OAS; 147 overall for NTSB.

⁵The 95 percent confidence intervals on these results were ± 2.1 years and ± 2.7 years, respectively. Late in the study, RAND acquired staffing records for the OAS for a larger sample of employees. Average tenure at NTSB for this sample was approximately one year less than that reported from the respondents to the RAND questionnaire, well within the confidence interval of the questionnaire sample.

⁶Fifty-eight of 112 OAS headquarters and regional staff answered the question regarding years of experience, a 52 percent response rate.



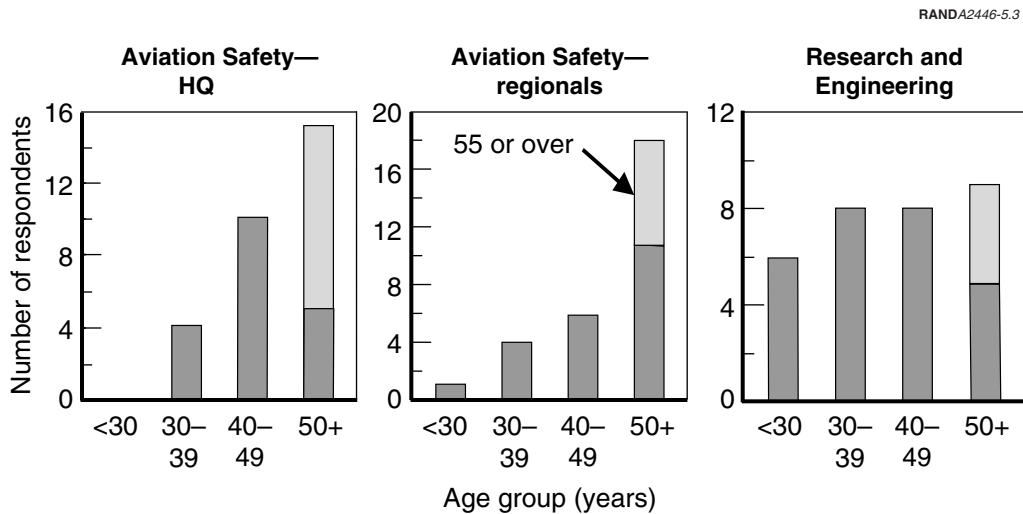
SOURCE: RAND Skills and Experience Questionnaire, administered to the NTSB staff, Summer 1998.

Figure 5.2--Experience Level of OAS Employees

The pattern of hiring highly experienced staff impacts the age distribution of the NTSB workforce and the niche within the aerospace industry salary structure in which the NTSB must compete.

As Figure 5.3 shows, the NTSB's experienced aviation workforce is skewed toward an older age distribution. Seventeen members (29 percent) of the OAS regional and headquarters staff responding to the RAND questionnaire reported being at least 55 years of age. This represents about 13 percent of the OAS technical staff and supervisory workforce as a whole, including those who did not respond to the survey. ORE staff had a more balanced age distribution.

Whereas age 55 represents an initial threshold for retirement, the Office of Personnel Management (OPM) has reported that federal workers on average retire at age 61 (Adelsberger, January 1998, p. 2). Twelve NTSB survey respondents were 61 or older, including six from the OAS and one from ORE. Because many NTSB staff join the agency in mid-career,



SOURCE: RAND Skills and Experience Questionnaire, administered to the NTSB staff, Summer 1998.

Figure 5.3--Age Distribution of Aviation Office Staff

they may tend to stay beyond age 55 to accrue full federal retirement benefits.

As the leading edge of the baby boom generation approaches retirement eligibility in 2001, the "graying" of the American workforce has been well documented. However, as Table 5.4 shows, the NTSB's aviation workforce age distribution appears to be more skewed than the distribution of the general working population in the United States in terms of both those at or above first retirement age and those who will reach that age within a decade.

"Block retirements" might create significant staffing problems at the NTSB, given the Safety Board's limited size and depth of staff. It has already faced this problem to some extent, and has used retention bonuses to encourage several employees to postpone their planned retirements (Case-Jacky, April 1999).⁷

The NTSB has also implemented accelerated hiring and mentoring programs to offset the impact of retirements. With a large fraction of its workforce in the 45-to-54 age group, NTSB managers will have to

⁷Retirements between fiscal years 1994 and 1998 ranged from four to nine per year. In the first three months of fiscal year 1999, the NTSB had already recorded six retirements (National Transportation Safety Board, 1999c).

Table 5.4
Surveyed Age Distribution of Selected NTSB Workers

Organization	Average Age (years)	Percentage of Respondents by Age		Number of Responses	Response rate (%)
		45-54	55+		
OAS--all	50	45	29	58	52
ORE	41	32	13	31	51
All NTSB	47 ^a	43	21	147	55
U.S workforce ^b	—	21	12	—	—

^aAs a point of reference, the DOD civilian workforce has an average age around 45 while the average age for NASA's workforce is 44 (Adelsberger, January 1998, pp. 2-3).

^bEmployed civilians (Jacobs and Zhang, 1998, p. 49).

devote considerable attention to the issue of its aging workforce in the coming decade in order to ensure that it maintains critical workforce skills.

Attrition has been moderate in recent years. From fiscal year 1995 through fiscal year 1998, voluntary resignations ranged from 6 to 8 percent of the workforce annually.⁸ Other than fiscal year 1995, when five air safety investigators from field offices resigned, no year stands out from the rest.⁹

The positive attitude of NTSB employees regarding the mission of the agency probably contributes to the low attrition rate. In interviews with RAND, NTSB employees frequently expressed concern about their workloads. However, they also repeatedly mentioned the interesting nature of their work and indicated a strong belief in the importance of their work to the traveling public.

⁸RAND tabulated all work separations from December 31, 1993, through January 5, 1999. Attrition calculations were based on voluntary resignations (NTSB personnel action 317) and the average size of the workforce in full-time equivalents during each fiscal year (National Transportation Safety Board, 1999c).

⁹Regional Air Safety Investigators communicated concerns about their working environment, career path, salary structure, and other issues to the chairman of the NTSB in 1997 (National Transportation Safety Board, October 1, 1997).

Salary Comparisons with Industry

During the next decade, the NTSB may need to accelerate the hiring of new staff in order to reduce the workload of individual staff members and offset coming retirements in its workforce. A central question then is whether the NTSB can attract and retain the class of experienced employees that it uses as accident investigators. Although a comprehensive examination of all the factors influencing the NTSB's ability to attract and retain employees was beyond the scope of this analysis, RAND performed a first-order assessment.

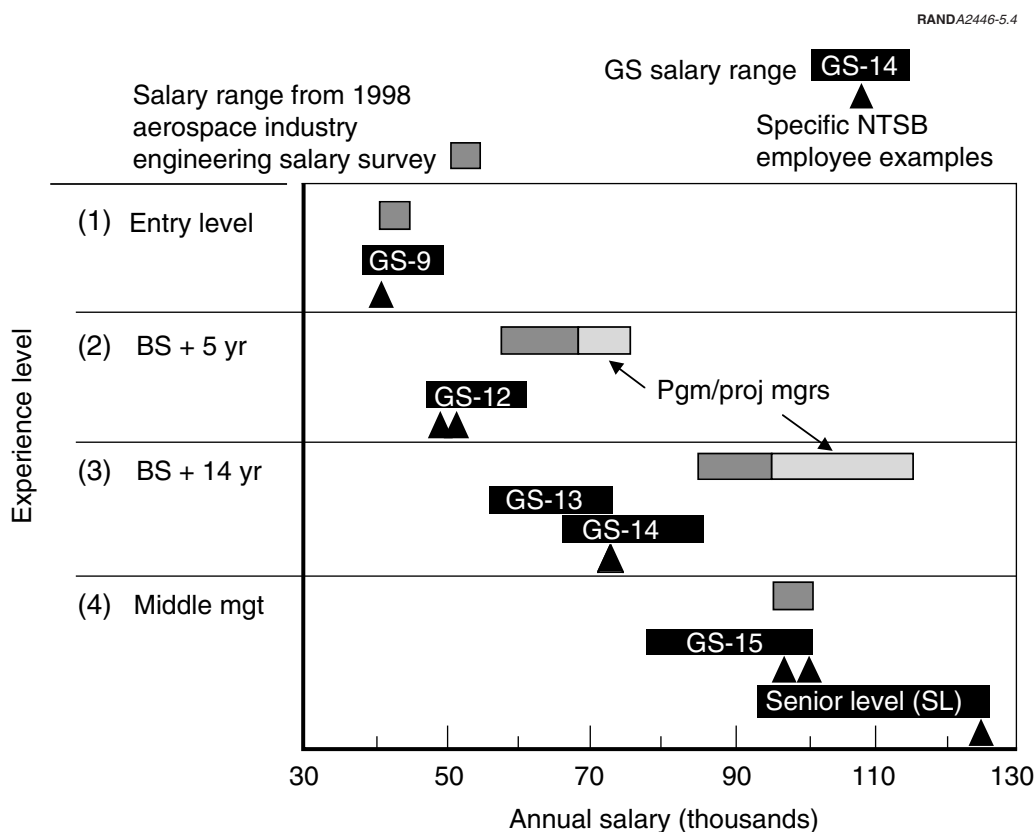
Because the NTSB recruits more employees from industry than from any other sector, RAND compared typical salaries of NTSB engineers with engineering salaries in the aerospace industry. The results showed that salaries for mid-career NTSB staff tend to lag behind those offered by the aerospace industry.

Figure 5.4 shows typical salary ranges in the aerospace industry for four experience levels, ranging from an entry-level new hire to an experienced middle-management employee.¹⁰ It also shows the premium the aerospace industry pays to program and project managers.

To compare aerospace industry salaries with those at the NTSB, RAND asked NTSB administrative officers from the ORE and OAS which government service (GS) grade is typically held by employees in each experience category (Francis, March 1999; Case-Jacky, April 1999). The salary ranges for the various GS grade levels are shown in Figure 5.4, along with examples of actual salaries of some NTSB employees.¹¹

¹⁰In 1998, Organization Resources Counselors Inc. compiled data on compensation and employment trends for more than 700 U.S. companies. They then developed a separate tabulation for 144 aerospace-related concerns, publicly and privately held, as well as some federally funded firms. Personal interviews and discussions with executives from 30 aerospace and aviation companies supplemented the survey results. ("Despite Consolidation, Aerospace Offers Attractive Employment Opportunities and Salaries," February 8, 1999, p. 83).

¹¹RAND used the Special Salary Rate Table 0414 for engineers through GS-12. For higher grades, the 1998 *General Schedule* for the Washington-Baltimore, DC-MD-VA-WV, area was used. The year 1998 was selected for comparison because the industry survey covered 1998 (U.S. Office of Personnel Management, 1998).



SOURCE: "Despite Consolidation, Aerospace Offers Attractive Employment Opportunities and Salaries," *Aviation Week & Space Technology*, February 8, 1999, p. 83; Personal communications with NTSB administrative officers, Spring 1999; U.S. Office of Personnel Management, 1998.

Figure 5.4--Comparison of NTSB and Aerospace Industry Salaries

Engineers joining the NTSB as a GS-9 Step 1 fall at the low end of the salary range for entry-level aerospace industry employees. These engineers do benefit from special civil service salary schedules for engineering occupations that exceed salaries in the General Schedule.

The disparity between NTSB and industry salaries increases for the more-experienced employees. The median grade for OAS employees is GS-13.¹² The salaries for these mid-career NTSB employees appear to lag behind typical aerospace industry salaries by the equivalent of at least one GS grade.

The disparity in salary levels is reduced for senior middle-management employees at the NTSB. Those in the upper levels of the GS-15

¹²From data provided by NTSB's Human Resources division, Fall 1998.

pay scale appear to have salaries broadly comparable with those in the aerospace industry survey.

The federal pay schedule also includes senior-level and scientific or professional positions. These positions, designed to compensate valuable senior employees who have reached the top step of the GS-15 scale, can provide a sizable premium over a GS-15 salary. The NTSB has rarely used these positions, although within the past several years one employee in the ORE was put on this salary schedule.

Federal agencies can use other types of incentive compensation, including hiring bonuses, retention bonuses, and the National Resource Specialist designations.^{13,14} The NTSB also has positions for three senior executive service people in the OAS at the director and deputy director levels, and two similar positions in ORE. These options provide some leverage for attracting or retaining key employees on a case by case basis, but they are not designed to address inherent competitive inequities in federal pay schedules.¹⁵

The NTSB must also measure its salary levels against those of other agencies of the federal government. The FAA, for example, is adopting a wide-ranging reform of its compensation system, replacing the traditional "grade-and-step" base pay method with a simplified structure of "pay bands," the value of which is determined by comparison with

¹³As of Spring 1999, the NTSB had recently used retention bonuses for five employees, three of whom were poised to retire, and two of whom were considering leaving the agency. Such bonuses are renewable; however, the additional compensation is not counted in the calculation of an employee's retirement pay (personal communication with administrative officer of the OAS, April 1999).

¹⁴Created by the OPM, the research specialist designation was designed to better compensate nonmanagerial employees who possess critical technical skills. Examples of NTSB staff who have held such positions include a structures and systems engineer, a meteorologist, and an ATC specialist (personal communication with administrative officer of the OAS, April 1999; internal NTSB staffing report, March 18, 1997).

¹⁵Another compensation challenge facing NTSB is that its headquarters and most of its regional and field offices are located in regions that most salary survey organizations classify as the "hottest" geographic areas for engineers. Anchorage, Miami, and Los Angeles are the only NTSB locations absent from those organizations' lists.

similar jobs in government and private industry (Federal Aviation Administration, June 17, 1998).

The new negotiated agreement with air traffic controllers abandons traditional GS grades and replaces them with air traffic control (ATC) levels. Under this plan, one-time increases in salary levels will be introduced over three years. They will range from a minimum of 5 percent to a maximum of 23 percent, and will average 12 percent nationwide (Haines, May 21, 1999).

Some FAA employees who are not covered by negotiated agreements, and whose functions may be considered analogous to some NTSB employees, are now involved in pilot programs of the FAA's Core Compensation System (Garvey, October 1, 1998). These programs are more flexible than the GS system under which NTSB currently operates.

The changes evolving at the FAA have not gone unnoticed by NTSB staff. Perceived compensation disparities between the FAA and the NTSB were noted in many survey responses and also in interviews. However, it is too soon to assess the long-term effects of these disparities on the ability of the NTSB to hire or retain qualified staff.

RAND did find anecdotal evidence that disparities in salary between private industry and the NTSB, and between the NTSB and other federal agencies, seem to adversely affect the NTSB's ability to hire the employees it needs. The director of OAS indicated that he has experienced difficulties in attracting experienced staff with skills (such as software engineering) that are in large demand in the general employment sector because of deficiencies in the NTSB salary structure. Key managerial positions have also been difficult to fill.

More research is needed to fully assess whether salary disparities will prevent the NTSB from attracting the high-caliber employees it needs to fulfill its mission. RAND's assessment compared only the salary dimension of compensation, and only for engineering disciplines. Future research should compare other elements of compensation for engineers and professionals from other disciplines, including psychologists, pilots, physical scientists, and others. Other nonmonetary factors affecting success in recruiting and retention also need to be considered.

WORKLOAD

RAND assessed the current workload at the NTSB to determine whether the size of its staff is adequate to meet accident investigation demands and whether it leaves time for staff to participate in training while away from daily accident investigation duties. The magnitude of the current workload also provides an indication of the ease or difficulty with which NTSB might expand into new activities consistent with its mission.

RAND measured workloads in terms of the hours NTSB investigators worked in aggregate as well as more disaggregated examinations of how they spent their time. Average workloads at the NTSB are quite heavy across all transportation modes. RAND's examination of how employees spent their time also raised some issues about work priorities at the NTSB.

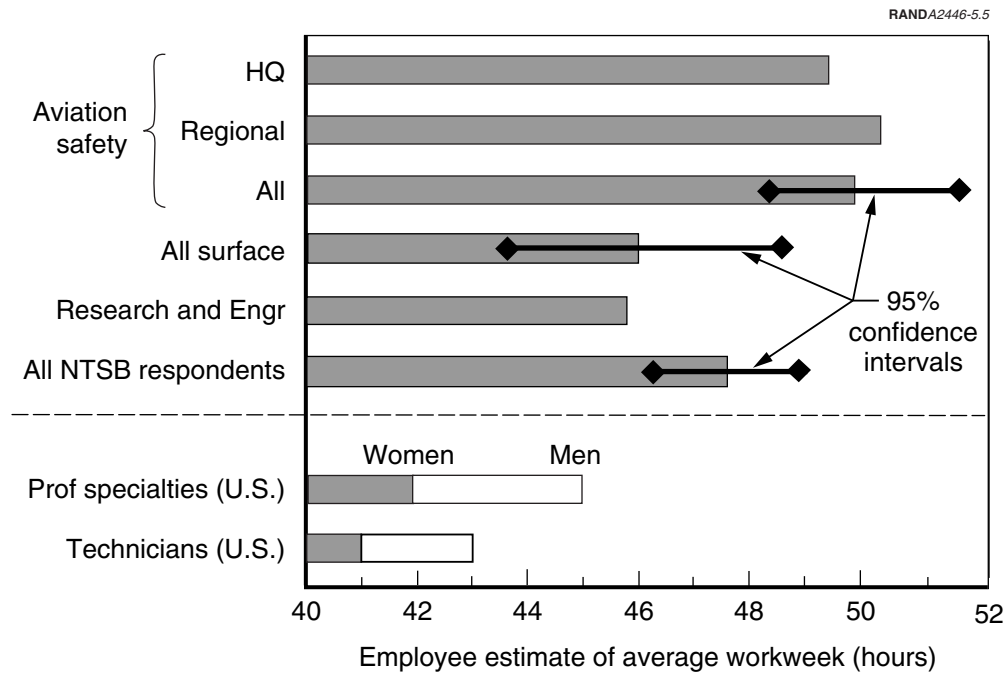
The NTSB's lack of a project-oriented management information system significantly hampers its ability to measure the workloads of its employees. Expenditures for goods and services are tracked by project (or accident investigation), but employee work time is not. This makes it virtually impossible to develop a breakdown of the human resources devoted to specific accident investigations.¹⁶ As a consequence, RAND used a variety of methods to measure workloads, including employee interviews, the structured survey, and data assembled from multiple internal NTSB data systems.

Aggregate Workloads

To estimate aggregate workloads at the NTSB, RAND reviewed (1) normal timekeeping data that recorded the typical 40-hour workweek, (2) budget data and personnel records to estimate overtime typically clocked by employees, (3) a prototype data system used by NTSB to track compensatory time,¹⁷ and (4) the survey results. Figure 5.5 presents a summary of these data.

¹⁶This issue is discussed further in Chapter 6.

¹⁷In lieu of overtime compensation, which is granted rather sparingly by the NTSB, employees often work excess hours and then are granted compensatory time off. The Budget Division of the Office of the Chief Financial Officer developed a prototype system for tracking



SOURCE: Developed from internal NTSB databases and RAND Skills and Experience Questionnaire; Hecker, October 1998, pp. 8-18.

Figure 5.5--Estimated Average Workweek Hours

The OAS staff at headquarters and in field offices reported an *average steady-state workweek* of approximately 50 hours. More than 8 out of 10 OAS investigators reported workweeks exceeding 44 hours.¹⁸ Like many other managerial and professional workers, NTSB staff are not compensated for all time worked in excess of 40 hours, although overtime and compensatory time arrangements do provide compensation for some of the extra hours worked.¹⁹

compensatory time accounts, both time used and unused (Libera, Fall 1998).

¹⁸Questionnaires were sent to 112 members of the OAS at headquarters and in the field. Replies answering the workweek question and noting organizational affiliation numbered 55, a 49 percent response rate. The standard deviation in the average workweek estimate was 6.3 hours and the 95 percent confidence interval was ± 1.7 hours. Eighty-one percent of headquarters OAS investigators and 89 percent of regional OAS investigators reported workweeks exceeding 44 hours.

¹⁹The internal NTSB timekeeping and budget records RAND reviewed indicated that aviation investigators usually recorded about two hours per week of overtime.

Periods of high overtime usage coincided with particularly intense activity during investigations of the TWA Flight 800 and the ValuJet Flight 592 accidents. During this time, the estimated continuous average workweek for senior investigators in the OAS approached 60 hours per week. Peak workloads can be substantially higher.

OAS personnel are not unique in working long hours, but their estimated workweek appears greater than that reported by surface transportation mode accident investigators at the NTSB.²⁰ As shown in the bottom portion of Figure 5.5, the estimated workweek of OAS personnel also appears to exceed that reported by other populations of full-time wage and salary workers, such as the professional specialty and technician occupational groups (Hecker, October 1998, p. 11).²¹ Table 5.5 more fully illustrates the differences in workweeks reported by NTSB personnel and other U.S. workers.

As the right-hand column of Table 5.5 indicates, a greater proportion of NTSB investigators report workweeks exceeding 44 hours (so-called *extended workweeks*) than do salaried U.S. workers as a whole and professional and technical workers. Of the major occupational groups tracked by the Consumer Population Survey, workers in the "executives, officials, and managers" group are most likely to work extended workweeks. However, the proportion of workers in this category who report working more than 44 hours per week (5 of 10 men and 3 of 10 women) is less than the proportion of NTSB investigators who report working extended hours (Hecker, October 1998, p. 9).

Assessments of the magnitude of the NTSB workweek should consider not only quantitative measures of workload but also the nature of the job of NTSB investigators. Although the NTSB is a small agency, its

²⁰Differences in workweeks reported by OAS respondents and the rest of NTSB respondents were statistically significant at the 99 percent confidence level. See Appendix D.

²¹Males in the occupational groups "clergy," "physicians," and "firefighters" report the highest typical weekly work hours among full-time wage and salary U.S. workers, in excess of 50 hours. Data derived from the 1977 Current Population Survey conducted by the Bureau of the Census for the Bureau of Labor Statistics. The Current Population Survey is a monthly survey of 50,000 households conducted by the Bureau of the Census for the Bureau of Labor Statistics.

Table 5.5
Comparison of Reported Workweeks

Sample	Average Weekly Hours	Percentage Reporting More Than 44 Hours
NTSB OAS personnel (HQ and regional)	50 ^a	85
NTSB surface transportation personnel (HQ and regional)	44-48 ^b	72
Full-time wage and salaried U.S. workers (men/women)	44/41 ^c	29/14
Professional specialty occupations, U.S. (men/women)	45/42	36/23
Technicians, U.S. (men/women)	43/41	21/9

^aSurvey data.

^bQuestionnaires were sent to 83 surface transportation investigators at headquarters and in the field. Replies answering the workweek question and noting organizational affiliation numbered 46, a 55 percent response rate. The standard deviation in the average workweek estimate was 8.5 hours and the 95 percent confidence interval was ± 2.5 hours.

^cU.S. workforce workweeks are based on data from the 1997 Current Population Survey, as summarized in Hecker, October 1998, pp. 8-18.

findings and recommendations can have multibillion-dollar implications and impact the safety of millions of travelers.

The size and timing of the investigators' workloads are largely determined by accident occurrences over which they have no control. Almost all NTSB employees wear pagers and to varying degrees are "on call" much of the time. When they reach an accident scene, which can be in just about any type of environment, they may be faced with dead or dying people, pathogens, toxic materials, and other physical hazards. They may also have to deal with jurisdictional disputes, intense media scrutiny, and concerned family members. In the midst of all this, they must act as managers, technologists, and investigators in order to collect and assess evidence to support subsequent efforts to identify the cause of an accident.

Pressure to avoid mistakes during an investigation and to avoid overlooking anything of significance is high because of the prominence of the NTSB as the nation's independent safety examiner. The intense

scrutiny that accident investigations receive from Congress, the media, the public, academia, companies, associations, states, foreign governments, regulatory agencies, private accident investigators, lawyers, and victims' families creates internal pressures at the NTSB to produce extremely complete and totally defensible analyses (Coarsey-Rader, January 22, 1998). In this respect, the qualitative demands of the accident investigation job can compound the quantitative impact of the long hours worked.

It is also important to assess whether their workloads prevent investigators from performing other tasks essential to the NTSB's mission, and whether the workloads impede investigators' ability to receive training to keep their skills current. NTSB staff repeatedly mentioned to RAND researchers that excessive workload was the single largest factor limiting their ability to participate in training they felt they should have.

More than half of the respondents to the RAND questionnaire indicated that they did not have adequate time to maintain and improve their professional skills. NTSB staff indicated that even if training budgets doubled or tripled, they would not be able to take advantage of additional training opportunities without first getting some workload relief. Addressing this issue appears to be a necessary prerequisite to improving staff training opportunities at the NTSB.

Workweek estimates that suggest NTSB investigators have an especially demanding workload are consistent with insights gained through interviews with people inside and outside the NTSB and from past results of other surveys and focus groups conducted at the NTSB (Coarsey-Rader, January 22, 1998; National Transportation Safety Board, October 1, 1997). RAND's results were also indirectly confirmed by observing the limited amount of time investigators spent on activities outside of day-to-day accident investigations, including formal training.

Notwithstanding the positive indications regarding the overall accuracy of the workload estimates, the fact that these estimates rely

at least in part on self-reported workweeks introduces an element of uncertainty.²²

The confidential questionnaire was distributed to every accident investigator at the NTSB across many geographic locations. The response rate on the workweek question was approximately 50 percent. The largest sample of data was collected from aviation safety investigators, the principal focus of the RAND analysis, and the resulting 95 percent confidence interval on their workweek results was ± 1.7 hours.

The survey results suggest that NTSB employees tend to work long workweeks. However, these results should be regarded as indicators rather than precise measurements. In the RAND assessment, the results were used as a departure point, prompting examinations of other indicators of workload levels, such as overtime payments.

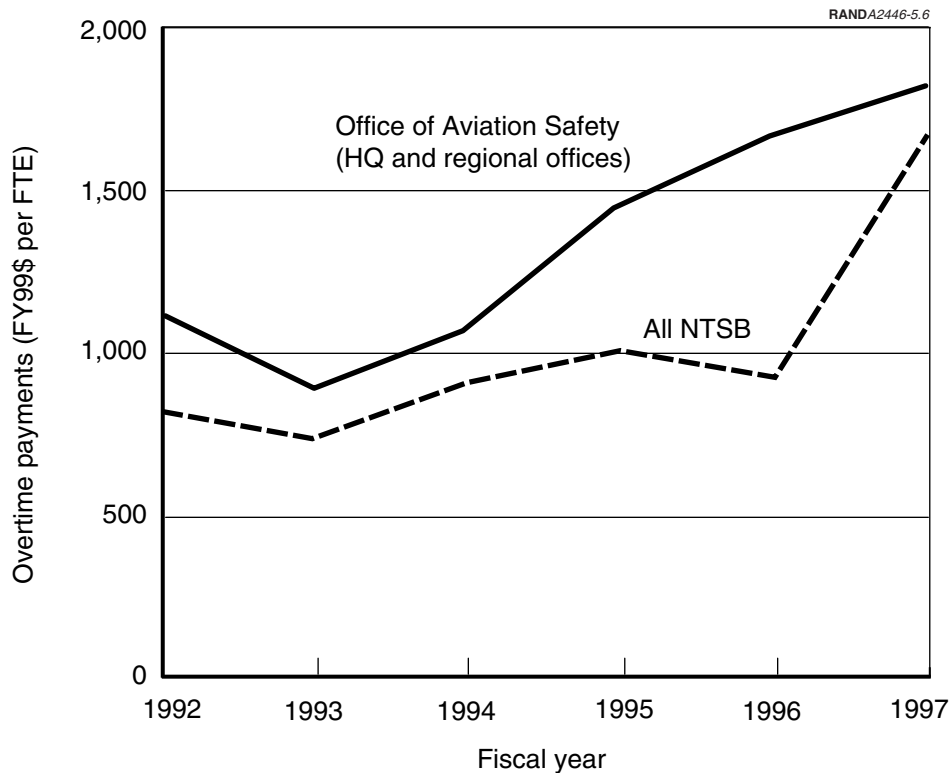
Trends in Overtime Payments

Figure 5.6 shows that trends in NTSB overtime pay also suggest a growing workload, particularly for the OAS, which shows a steady increase in overtime payments since 1993. Between fiscal year 1992 and fiscal year 1997, the OAS accounted for a disproportionate share of overtime payments (49 percent), relative to both its proportion of the NTSB workforce (37 percent) and the growth in its staff.²³

Collectively, the quantitative and qualitative measurements assembled during the RAND study all suggest a continued heavy workload for the NTSB staff that, if left unaddressed, will continue to impede NTSB efforts to provide training opportunities to its employees.

²²The accuracy of self-reported workweeks is the subject of considerable research, as investigators try to measure trends in working hours and more generally how working Americans spend their time. Appendix D discusses views on the efficacy of various approaches for measuring workweeks.

²³Overtime is used rather sparingly at the NTSB, and when used, is not paid at a rate commensurate with the GS grade of typical investigators. Because Air Safety Investigators are exempt from the Fair Labor Standards Act, they are entitled to a maximum of 1.5 times the GS-10 step 1 hourly rate. This frequently results in investigators being paid less than their regular hourly rate when working overtime (National Transportation Safety Board, October 1, 1997, pp. 4,5). In May 1999, the NTSB asked Congress for more flexibility in prescribing reasonable rates of overtime pay (Hall, May 6, 1999).



SOURCE: Developed from internal NTSB timekeeping and budget records.

Figure 5.6--NTSB Overtime Payments, 1992 to 1997

Headquarters Investigative Activities

To better understand what type of activities NTSB employees perform during their extended workweeks, we examined the specific kinds of aircraft accident investigations typically performed by headquarters and regional office investigators. Handling major airline accidents and incidents is the job of the headquarters-based OAS Major Investigations Division. A breakdown of that division's investigative activity for the last decade is shown in Figure 5.7. NTSB headquarters has dealt with an average of seven major accidents per year, a number that has not shown a downward trend. As previously mentioned, these accidents have tended to involve increasingly complex investigations; RAND expects this trend to continue.

Because support to foreign accident investigations is an important element of NTSB's responsibilities, one must look beyond the

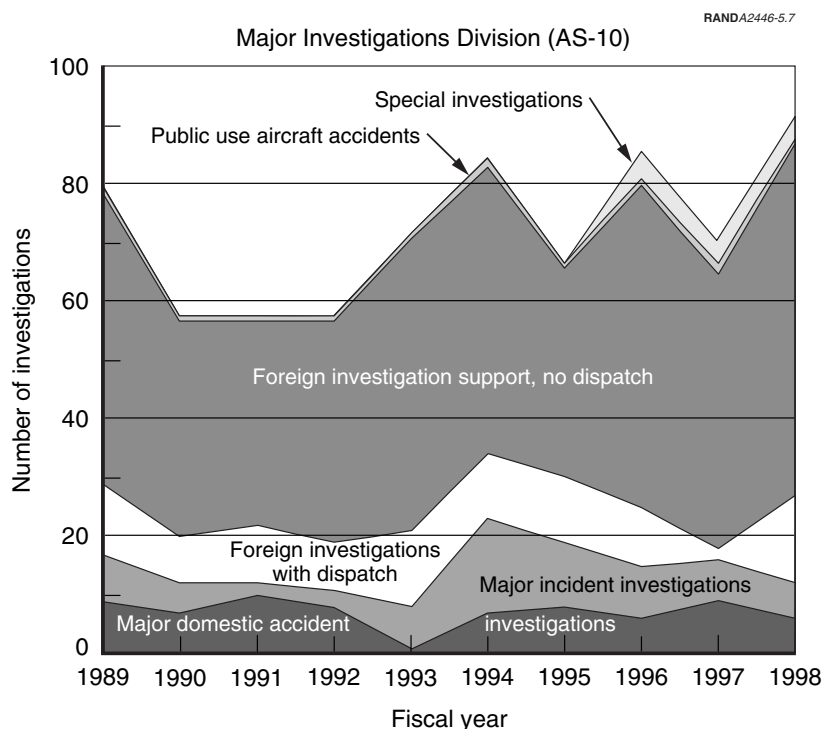


Figure 5.7--Investigative Activity, Major Investigations Division, 1989 to 1998

investigation of major U.S. air carrier accidents to get a complete picture of the OAS workload (see Figure 5.7). During the past decade, the OAS Major Investigations Division supported an average of 46 foreign accident investigations per year without dispatching investigators,²⁴ and on average dispatched personnel to another 10 foreign investigations per year.²⁵ This highlights the fact that a significant residual workload could remain even with progress in reducing accident rates of U.S. air carriers.

²⁴ For example, NTSB support often takes the form of reading and interpreting the contents of voice and flight data recorders recovered from overseas accidents. The OAS would normally do this in concert with the Vehicle Recorders branch of ORE.

²⁵ Work hours devoted to each dispatch would provide a more informative picture of the distribution of effort at the NTSB. Unfortunately, because the personnel timekeeping system used by the NTSB does not track efforts by project (or accident), such information is not available. See Chapter 6 for more details about the NTSB's timekeeping system.

Support to foreign accident investigations can be relatively minor or can represent a major effort, as exemplified by the NTSB's support of Canadian investigators in the MD-11 Swissair 111 accident in 1998 and support of Colombian investigators in the 1995 crash of an American Airlines Boeing 757 in Cali, Colombia. In the case of a foreign accident involving a U.S.-manufactured aircraft, NTSB personnel from regional offices may also be dispatched to the manufacturer's facilities to support investigations being managed by NTSB headquarters or by a foreign accident investigation organization.²⁶

Ten percent of the investigations shown in Figure 5.7 involve U.S. air carrier incidents. Although the number of incidents the NTSB investigated during the 1990s increased, the bulk of the NTSB's resources remains dedicated to accident investigations. RAND interviews with the NTSB staff and examination of NTSB investigative activities reports confirmed that the NTSB is organizationally focused and expends far more resources on investigating accidents than incidents.

Chapter 6 examines the implications of taking a more proactive stance with respect to accident prevention through expanded examination of aircraft incidents. These proactive efforts could help the NTSB better meet its mission objectives and support nationwide goals for continued reductions in aviation accident fatalities. However, absent any augmentation to the workforce or a change in NTSB priorities, such a policy change could increase workloads beyond what the NTSB staff is experiencing today.

Looking to the future, the mix of accident investigation activities performed by NTSB headquarters personnel may change, while demands for their investigative services will likely remain strong because of projected robust air traffic growth worldwide. Absolute numbers of accidents may decline, but the complex systems involved in the remaining accidents could make those accidents much harder to

²⁶During the early stages of the Swissair 111 investigation, personnel from the NTSB's Seattle and Los Angeles regional offices were dispatched to Boeing facilities in Seattle and Long Beach (Mucho, March 1999; McGuire, Fall 1998).

diagnose. Additionally, the need to support foreign investigations will place a continuous demand on NTSB resources.

Regional Investigative Activities

Six regional NTSB offices and four smaller field offices across the contiguous 48 states and Alaska collectively investigate approximately 2,000 GA accidents per year.²⁷ In addition, field personnel often participate in, and in some cases lead, major accident investigations.²⁸

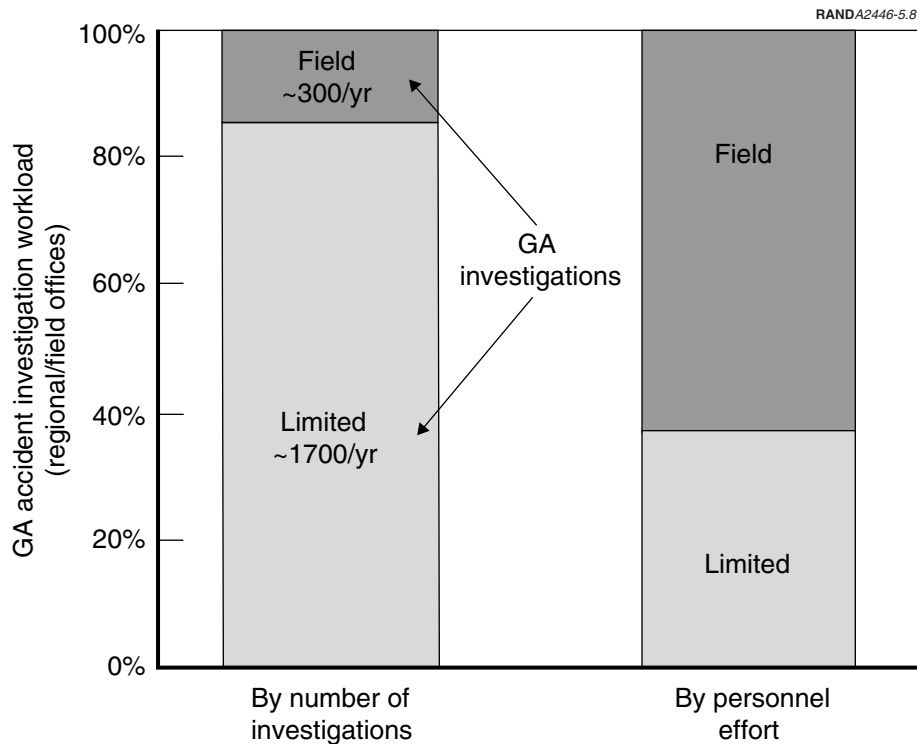
Although there are many more GA investigations than major air carrier accident investigations, they are normally of much shorter duration. A typical regional office investigates approximately 300 accidents per year. At one regional office visited by RAND researchers, the average investigator was carrying more than 20 open investigations (National Transportation Safety Board, September 30, 1998). Because of the volume of accidents, regional offices apply their own criteria to determine the depth of each investigation. While some offices apply similar criteria, there is no NTSB-wide set of standards. This variability impacts the workload at various regional offices and the resources needed for investigations.

As explained in Chapter 2, GA accident investigations fall into two of the five major categories of aviation accident investigations: "limited investigations," which are accomplished by gathering facts over the telephone about the circumstances of an accident, and "field investigations," in which investigators go to the accident site.

Limited investigations typically consume 10 to 12 investigator hours, whereas field investigations might consume 10 times that number of investigator hours. Figure 5.8 shows that more than 80 percent of

²⁷General aviation encompasses companies using their own airplanes for business transportation, air charters, air taxis, personal and recreational flying, emergency medical evacuation, agricultural flying, traffic and aerial observation, and flight training. After a long decline, activity in this aviation sector has begun to grow again (see Figure 3.13 in Chapter 3).

²⁸Because more than half the personnel in the OAS are assigned to regional and field offices, GA accident investigation represents a significant resource expenditure for the NTSB.



SOURCE: Mucho, 1999; McGuire, Fall 1998.

**Figure 5.8--General Aviation Accident Workload,
Field vs. Limited Investigations**

accident investigations are in the limited category, but the extra effort required for field investigations means that they end up accounting for about 62 percent of the effort.

Most, but not all, fatal GA accidents are treated as field investigations. Four regional offices reportedly treat some fatal accidents as limited investigations if after collecting the facts by telephone they are reasonably assured of the cause of the accident.

Comparisons of GA and air carrier accident statistics do not provide a clear indication of appropriate resource allocations for accident investigations. GA accident investigation accounts for a substantial fraction of NTSB resources, and indeed, many more accidents and typically five times more fatalities occur annually in the GA sector than in the air carrier sector. Conversely, a single air carrier accident can have far broader implications for the traveling public than

Table 5.6
General Aviation and Air Carrier Comparisons

Metric	General Aviation	Air Carrier
Staff FTE (FY98)	86 (OAS regions)	63 (OAS HQ)
Budget (FY98)	\$6.7M (OAS regions)	\$9.2M (OAS HQ)
Accidents/year	~2,000	~14 major domestic accidents/incidents
Average fatalities/year (88-97)	746	149
Exposure-domestic operations (FY96) (million passenger hours)	79	1,050

SOURCE: Internal NTSB staffing databases; Internal NTSB budget records; NTSB Aviation Accident Database, 1999; Department of Transportation, 1998, Chapter 1 and Appendix A.

a single GA accident. Further, as Table 5.6 indicates, in terms of passenger hours, the U.S. traveling public uses air carrier transportation 13 times more than GA transportation on an annual basis.

In interviews, many members of the aviation community expressed dissatisfaction with the current NTSB approach to resource allocation for GA accident investigations. Several salient observations emerged in these discussions. One frequent comment was that the NTSB should either hire more investigators so they can do more thorough GA accident investigations, or alternatively, be more selective in choosing which accidents to investigate so investigators can devote more time to a smaller set of accidents. Others within the NTSB argue that all accidents should receive at least limited investigations to prevent safety issues with potentially broad implications from going unnoticed, and to maintain the integrity of the unique GA accident database that the NTSB maintains.

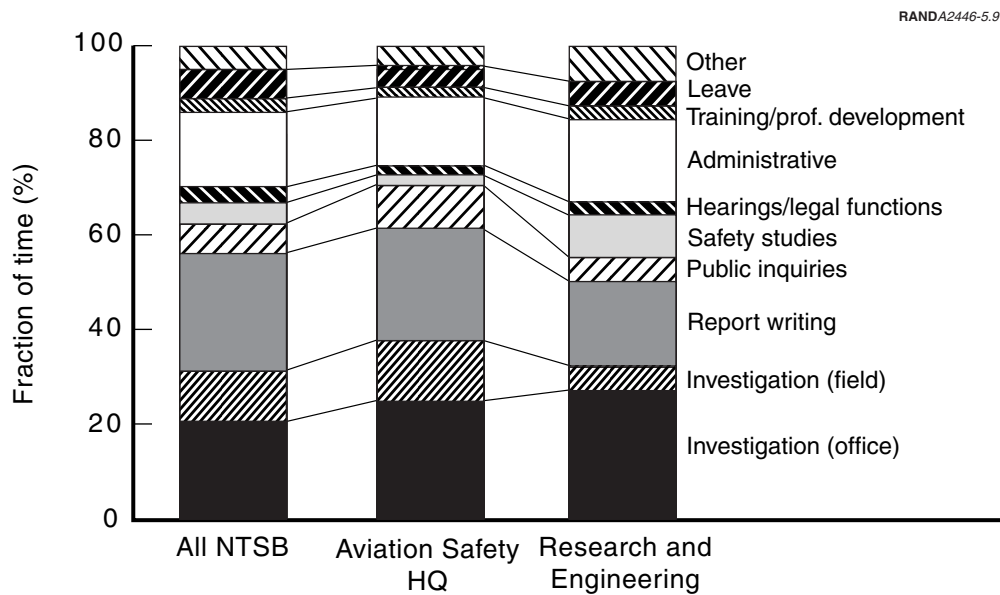
In citing the value of GA investigations, NTSB staff members noted that safety recommendations drawn from GA investigations often have important implications for air carrier operations. However, a more direct approach--such as expanding the analysis of air carrier incidents--might increase the yield of safety recommendations relevant to air carrier operations. To ensure appropriate resource allocations, the NTSB must weigh its resource expenditures for air carrier and GA

accident investigations against the benefits the traveling public derives from each of these two categories of investigations.

How NTSB Personnel Spend Their Work Time

RAND also examined how NTSB investigators allocated their work time. The questionnaire used to query NTSB personnel about their workweek asked respondents about the relative percentage of time they spent on various activities. Respondents were offered a structured set of choices, including "other," as well as space to enter text freely.²⁹

The results helped RAND identify how NTSB investigators prioritize their activities and it provided self-reported estimates of how much time they spent in training. RAND used these estimates to gain a first-order assessment of the training situation at NTSB. Figure 5.9 shows that for the NTSB as a whole, and for OAS and ORE at NTSB headquarters, investigators on average spend more than half their time investigating accidents and writing reports.



SOURCE: RAND Skills and Experience Questionnaire.

Figure 5.9--Fraction of Time NTSB Staff Spend in Work Activities

²⁹This question drew 149 responses across the NTSB from 269 distributed questionnaires. See Appendix E for the specific format of the question on the distribution of activities.

The questionnaire specifically included a category to quantify how much time NTSB staff spent answering public inquiries. In interviews with RAND, NTSB staff expressed concern regarding the priority NTSB management attached to this activity relative to investigators' other duties. Given NTSB management's expressed desire to improve the quality and quantity of training at the agency, it is of considerable interest that their employees estimate they spend significantly more time answering public inquiries than they do in training.

As a public agency, the NTSB's mission includes informing the public of its accident investigation findings. It uses many techniques to disseminate this information, including holding public hearings and press conferences, issuing accident reports and safety studies, conducting public outreach activities, and publishing material on its Internet site. By congressional direction, the NTSB has also established an office of family affairs to provide information and support to the families of accident victims. In addition, NTSB staff also communicate directly with the public by answering letters or responding to other communications regarding accident theories, safety ideas, and other topics.

RAND survey respondents estimated spending an average of more than 6 percent of their time answering public inquiries and only 3.4 percent of their time in training activities. Respondents from the OAS at headquarters estimated spending almost 9 percent of their time answering public inquiries and only 2 percent of their time in training (about one week a year).

Some extreme values reported by individual respondents skewed the averages. The median values depicted in Table 5.7 provide a more representative picture of the time the NTSB staff estimates it typically spends answering public inquiries relative to time spent in training.³⁰ As Table 5.7 shows, personnel from OAS headquarters and regional offices (labeled "All OAS") typically reported spending 2.5 times more time

³⁰The median, the value above or below which lies an equal number of observations, generally provides a better measure of central tendency than the mean when there are some extremely large or small observations (Lapin, 1975, pp. 43-45).

Table 5.7
Time Spent Answering Public Inquiries and in Training
(Percentage of Respondent's Time)

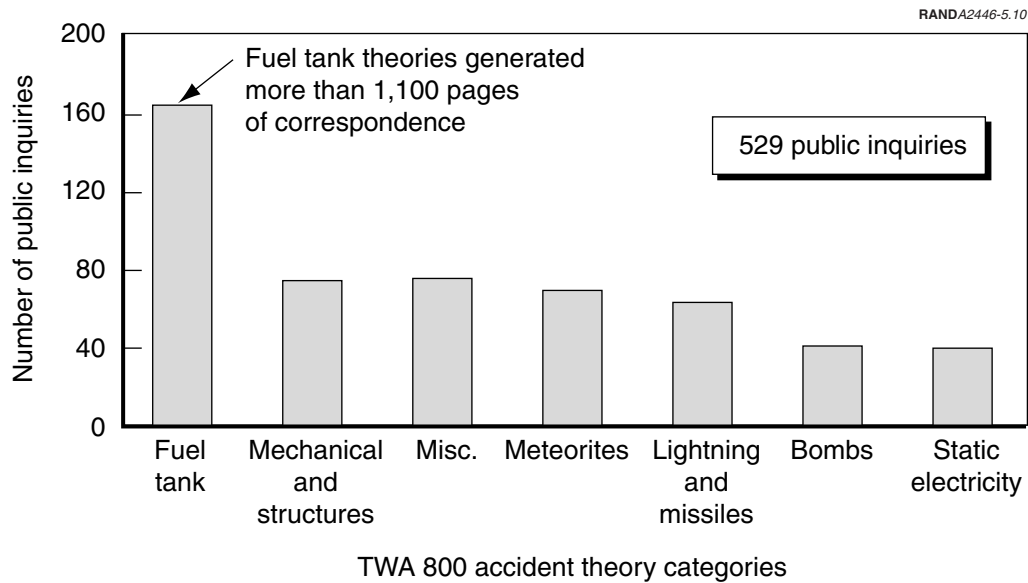
Office	Answering Public Inquiries		In Training		Survey	
	Mean	Median	Mean	Median	Response	Population
OAS-HQ	8.8	5.0	2.0	2.0	29	56
OAS-Regional	6.2	5.0	2.8	3.0	29	56
All OAS	7.5	5.0	2.4	2.0	58	112
ORE	5.0	2.0	3.5	3.0	31	61
All NTSB	6.2	5.0	3.4	3.0	150	269

answering public inquiries than in training (5 percent versus 2 percent). Overall, the estimates indicate the typical NTSB respondent across all organizations spent more time answering public inquiries than in training.

NTSB staff members' experience answering public inquiries about the crash and investigation of TWA Flight 800 puts these statistics into sharper focus. During that investigation, the NTSB staff were inundated with public inquiries about accident theories. Through its "mail control" process, the NTSB date-stamped, sorted, catalogued, and routed hundreds of pieces of correspondence received during the course of the investigation. As Figure 5.10 shows, 529 separate public inquiries offered theories about accident causes. Letters from the public and the NTSB's replies concerning fuel tank theories alone amounted to more than 1,100 pages of correspondence. Although not all inquiries received a reply, and some received only a brief courtesy reply, investigators were asked to prepare technical replies to a number of inquiries.³¹

The burden of replying to public inquiries was not unique to the TWA Flight 800 investigation, and many NTSB staff members in interviews with RAND, without being prompted, mentioned the time commitment to

³¹Inquiries were sorted into seven categories: missiles and lightning strikes, fuel tank (two volumes), mechanical malfunctions and structural failures, bombs, meteorites, static electricity, and miscellaneous (letters to NTSB from the public regarding the TWA Flight 800 accident, 1996-1998). Letters addressing accident theories from attorneys representing various parties in the accident were another major source of correspondence.



SOURCE: Tabulation of letters to the NTSB from the public regarding the TWA flight 800 accident, 1996-1998.

Figure 5.10--Public Inquiries Following Crash of TWA Flight 800

public inquiries. Investigators expect the level of public inquiries to remain high in the future because the NTSB posts the factual record of its accident investigations on the Safety Board's Web site. The speed and breadth of Internet communication have facilitated interaction among accident theorists. Following a major accident, the number and intensity of news group postings multiply.

Given the heavy workload in all transportation modes, the degree of staff time devoted to answering public inquiries deserves careful examination, particularly because the NTSB already uses many other channels to disseminate information to the public. Furthermore, senior investigators could recall no instance in which an accident theory proposed by a member of the public contributed materially to an NTSB air carrier accident investigation.

TRAINING

NTSB investigators draw on their management, investigative, and technical skills to investigate accidents. Management skills are needed to coordinate the activities of the myriad entities involved in an accident investigation so that an objective assessment of the accident

cause can be reached. Investigative skills are needed to collect, catalog, and evaluate all the facts associated with an accident. Technical skills are needed to understand the functioning of the aircraft, and the airport and airways system within which it operates. Rapid advances in aircraft technology and other elements of the aviation environment make technical skills more "perishable" than management or investigative skills, which are less likely to become outdated.

The party process can work effectively only if investigators (1) possess sufficient skills and experience to command the trust and respect of the parties, and (2) ask the right questions, critically evaluate input from parties, and correctly assemble the facts. NTSB personnel must quickly and unequivocally demonstrate leadership and command of an investigation. Training helps investigators renew technical skills and keep abreast of new developments in aviation that they need to accomplish their investigative tasks.

To keep their skills current, NTSB investigators undertake various training activities. RAND examined the following aspects of training at the NTSB:

- Rationale for training
- Amount of training
- Sources of training
- Administration of the training process
- Training content.

RAND's assessment indicates that training opportunities for NTSB investigators are constrained by heavy workload, inadequate funding, and other factors, particularly when measured against the amount of training other members of the aviation community receive. Much of the training that is offered takes place in-house because the NTSB utilizes outside training resources to only a limited degree. The training that does occur is balanced across management, investigative, and technical areas. However, the emerging aviation environment (discussed in Chapter 3) will pose new challenges that may require some changes in the emphasis among these areas.

Rationale for Training

Interviews with NTSB managers and technical staff, and other members of the aviation community, revealed consistent views on the need for enhanced training at the NTSB. These interviews also outlined the typical pattern of training at the NTSB. They complement quantitative assessments of the current state of training at the NTSB.

Aircraft operators recognize the importance of on-the-job and supplemental off-the-job training to maintain the skills of their workforce. Table 5.8 shows that sharp distinctions exist between the airline training experience and the training environment at the NTSB.

Because airline officials know which equipment their personnel must operate and maintain, they can gauge the diversity of skills required to maintain and operate their fleets. The NTSB is in a more reactive posture, driven by the stochastic nature of accident events. Any kind of airplane can crash at any time, from the newest airliner to a vintage transport. The skill set required for investigations varies unpredictably from accident to accident.

Airline personnel receive both formal and informal on-the-job training that usually occurs on a regular basis. In contrast, NTSB

Table 5.8
Airline vs. NTSB Training Factors

Factor	Airline	NTSB
Predictability of skill needs	High	Low
Diversity of skill needs	Moderate ³²	High
Diversity of equipment	Moderate	High
On-the-job professional training	Extensive	Limited
Predictability of on-the-job training experience	High	Low
Off the job training	Extensive	Limited
Predictability of off-the-job training experience	High	Low

SOURCE: Based on RAND interviews with airline operators and NTSB personnel, 1998-1999.

³²This rating is not meant to underrate the skills needed by airline employees, but only to indicate that NTSB investigators must possess project management and investigative skills in addition to technical knowledge about flying and maintaining aircraft.

investigators do not fly or maintain airplanes on a regular basis; therefore, they do not have comparable opportunities to become familiar with equipment and operational procedures, although the on-the-job experience they do receive can develop accident investigation skills.

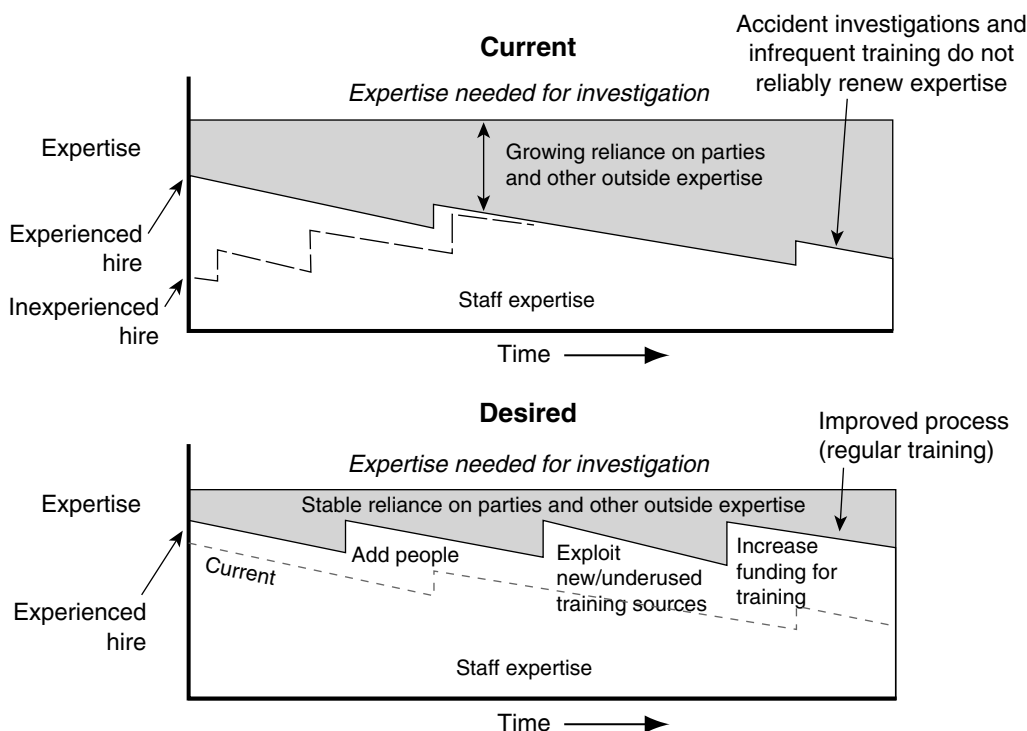
Because of the unpredictability of accident events, NTSB investigators may only become familiar with new equipment as a by-product of their daily activities if such an aircraft is involved in an accident. There is no guarantee that investigating an accident involving an older aircraft, such as a Boeing 747-100, will prepare an investigator for a subsequent investigation involving a more modern airliner, such as an Airbus or a Boeing 777.

To supplement on-the-job training, airlines provide extensive, regularly scheduled, formal off-the-job training to meet their own internal training requirements and those of the FAA. In the case of flight training, the type and amount of this formal annual training is determined by the employee's job duties rather than by his or her age or experience. For instance, every pilot, irrespective of experience, must undergo a specified amount of formal training every year. The amount of training varies according to whether the pilot is keeping the same duties on the same type of aircraft, or is transitioning to new duties or moving to another aircraft type (Landry, June 1999). In contrast, the typical NTSB employee receives much less formal training, and the demands of accident investigation can disrupt scheduled training.

This contrast between the level of formal training received by airline personnel and NTSB staff underscores one of the reasons the NTSB relies on the party system: Its investigators cannot be expected to possess intimate design or operational knowledge on the entire scope of equipment every airline operates. Significantly, while airlines offer appreciable on-the-job training opportunities, air carriers also augment that learning with extensive outside training. NTSB personnel, on the other hand, have limited opportunities for systematically and regularly updating their technical knowledge of aircraft while on the job and, for a variety of reasons, undergo little formal off-the-job training.

The potential consequences of this limited technical training are depicted at the top of Figure 5.11. As illustrated earlier in this

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SOURCE: Notional depiction based on interviews with NTSB staff and other members of the aviation community, 1998–1999.

Figure 5.11--Two Notional Views of the NTSB Training Cycle

chapter, the NTSB often hires experienced personnel who enter the agency at a high skill level. Over time, however, as workload demands limit the frequency and extent of training, technical skills diminish, forcing the NTSB to rely increasingly on the party process to supply the technical expertise needed for accident investigations. The NTSB tries to manage the level of party participation so that party involvement does not threaten the independence of its investigations.

At times, the NTSB hires relatively inexperienced individuals and devotes comparatively greater resources to training them to acquire the skills needed to become productive investigators. Whether this sort of employee development path is in fact effective is somewhat unclear. Some respondents to the RAND questionnaire asserted that the NTSB cannot successfully train an inexperienced person in such a manner. Other respondents expressed concern that the high cost of training

inexperienced employees leaves limited resources for training other employees.

Frustration was also expressed about newly hired employees who may not be able to immediately shoulder a part of the investigative burden, thereby creating even more work for experienced employees. Seemingly, with its limited staffing depth and heavy workload, the NTSB is not in a good position to divert senior personnel from their regular work to engage in mentoring duties.

The current state of training at the NTSB, depicted in Figure 5.11, implies a steady degradation of staff skills, a matter of concern for an agency with a national safety role. The current situation is of particular concern because, as detailed in Chapter 3, the NTSB is facing more complex accident investigations that increasingly involve design-related issues associated with high-level systems integration.

Because aircraft safety is a complex function involving the actions of many entities, including airlines, the FAA, manufacturers, and the NTSB, it would be difficult to directly attribute any change in aircraft safety to the training situation at the NTSB. The impact of insufficient training is much more subtle, such as the technical question that goes unasked or the possible accident cause that goes unexplored because the investigator does not possess adequate technical knowledge of a particular system.

Investigators have related instances of misrepresentation by parties that were uncovered only because of the technical knowledge of the NTSB staff,³³ underscoring the need to maintain a skilled staff through a combination of hiring and training.

One party representative from the aviation community privately stated to RAND researchers that information would be given to the NTSB investigators only if "they [the investigators] knew to ask the right question[s]." There is no definitive way to determine how pervasive this attitude is, but it illustrates how important it is for investigators to have enough technical knowledge to elicit needed information from parties.

³³Chapter 4 discusses the relationship between parties and the NTSB, and the pressures that can shape that relationship.

Many individuals interviewed by RAND felt that a training cycle, such as in the one shown at the bottom of Figure 5.11, could address many of the shortcomings of the current situation. In this desired scenario, the NTSB hires experienced employees who would be trained more frequently and to a greater extent, renewing their skills on a regular basis. Consequently, the NTSB's dependence on parties and outside expertise would stabilize, thereby safeguarding the integrity of the accident investigation process.

Because of the nature of career paths at the NTSB, this skill renewal process should, in principle, occur throughout an investigator's career. In the words of the NTSB chairman, "[b]ecause of the small size of the NTSB workforce, investigators tend to stay on the front lines of accident investigation throughout their careers, with few options for alternative office positions (Hall, May 6, 1999)."

We now turn from a qualitative description to more quantitative measures of training at the NTSB.

Amount of Training

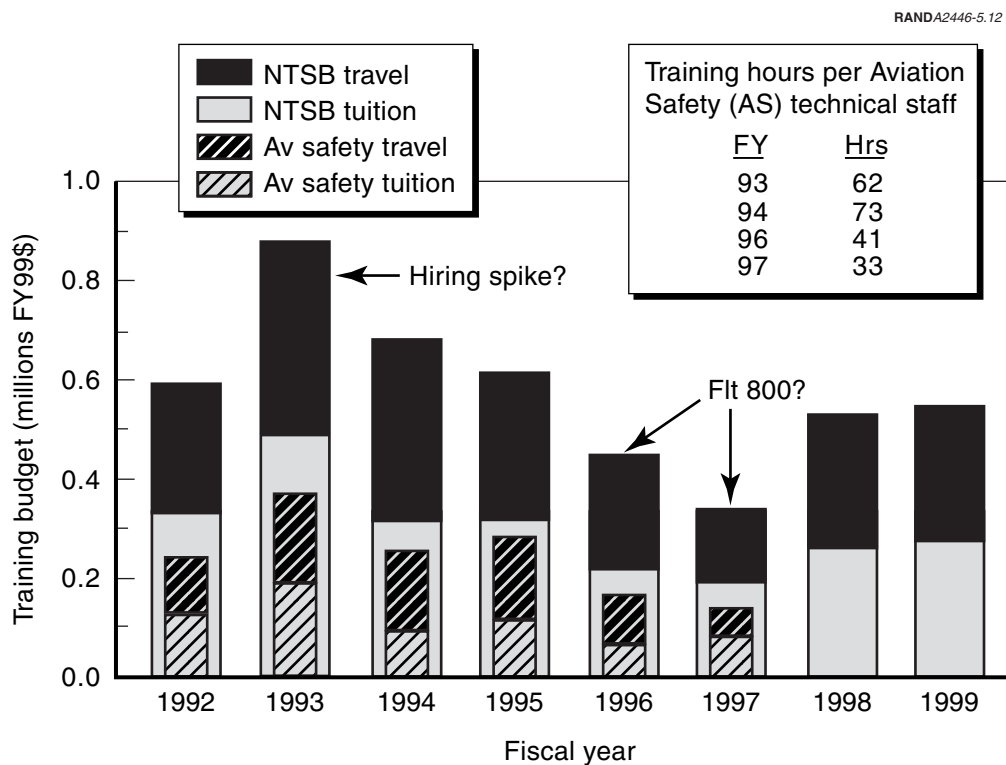
RAND used three metrics to characterize the amount of training activity at NTSB:

- tuition and travel expenditures for training derived from NTSB fiscal records
- technical staff training hours as recorded by administrative officers at the NTSB
- self-reported estimates of training activity from the RAND questionnaire.

Tuition and travel expenditures are routinely tracked in the NTSB's accounting system. Administrative officers prepare tabulations of training hours for submittal in response to congressional inquiries. Respondents to the RAND questionnaire estimated the fraction of their work time spent in training, usually expressing the estimate to the nearest percent (equivalent to approximately 2.5 days) and occasionally to a half percent (equivalent to approximately 1.3 days).

Figure 5.12 shows that NTSB expenditures for training OAS employees fluctuated significantly during the 1990s.³⁴ The 1999 NTSB training budget, adjusted for inflation, approaches levels achieved during several fiscal years earlier in the 1990s; however, because of growth in the NTSB staff, the budgeted \$1,400 per employee for training in fiscal year 1999 is approximately 81 percent of the fiscal year 1992 level.³⁵

The NTSB does not have historical records that would explain with certainty the cause of fluctuations in training expenditures. An influx of new employees may account partially for the high expenditures for



SOURCE: Internal NTSB budget records, various years; Congressional submittals of training hours, various years.

Figure 5.12--NTSB Travel and Tuition Budgets for Training, 1992 to 1999

³⁴Tuition and travel costs comprise incremental training expenses. Salary is not an incremental cost because employees are already on the NTSB payroll. An opportunity cost is associated with having employees away from the job while attending formal training.

³⁵Data drawn from internal NTSB staffing and budget records.

training in 1993.³⁶ The time demands placed on investigators following the crash of TWA Flight 800 and ValuJet Flight 592 in the same year may have contributed to the decrease in training expenditures in the OAS in 1996 and 1997.

The NTSB's response to congressional inquiries regarding the training hours expended by the NTSB technical staff is a better measure of training activity than tuition and travel expenditures. For the years shown in Figure 5.12, OAS personnel averaged four to nine days of formal training per year, with appreciably less training in recent years.³⁷

In interviews with RAND researchers, NTSB employees repeatedly asserted that heavy workloads prevented them from receiving the training they needed. We tested the relationship between the amount of training (measured in terms of hours per full-time employee for the OAS and in terms of expenditures per full-time employee for the NTSB as a whole) and workload (represented by overtime expenditures per full-time employee). Both measures of training were negatively correlated with increased workload; that is, as workload increased, training tended to decrease.³⁸ As has been frequently noted in this report, resolving the workload issue is an important part of any integrated effort to improve training at NTSB.

Using results from the RAND questionnaire, we tested for differences in the amount of training reported by investigators having varying experience levels and who were from different NTSB organizations. Figure 5.13 shows that employees with less experience

³⁶Each new employee attends a basic accident investigation course taught by the NTSB.

³⁷Drawn from NTSB congressional submittals for fiscal years 1993, 1994, 1996, and 1997. These submittals describe the kind of training, hours, and job classification of employees receiving the training. This measurement of training hours brackets the self-reported level of training activity--roughly six days per year--estimated by OAS personnel who responded to the RAND Skills and Experience Questionnaire in Summer 1998.

³⁸Training hours and training expenditures comparisons included only four and six years of data, respectively. Both measures were negatively correlated with increases in overtime expenditures, having coefficients of determination (R-squared) of .90 and .62, respectively.

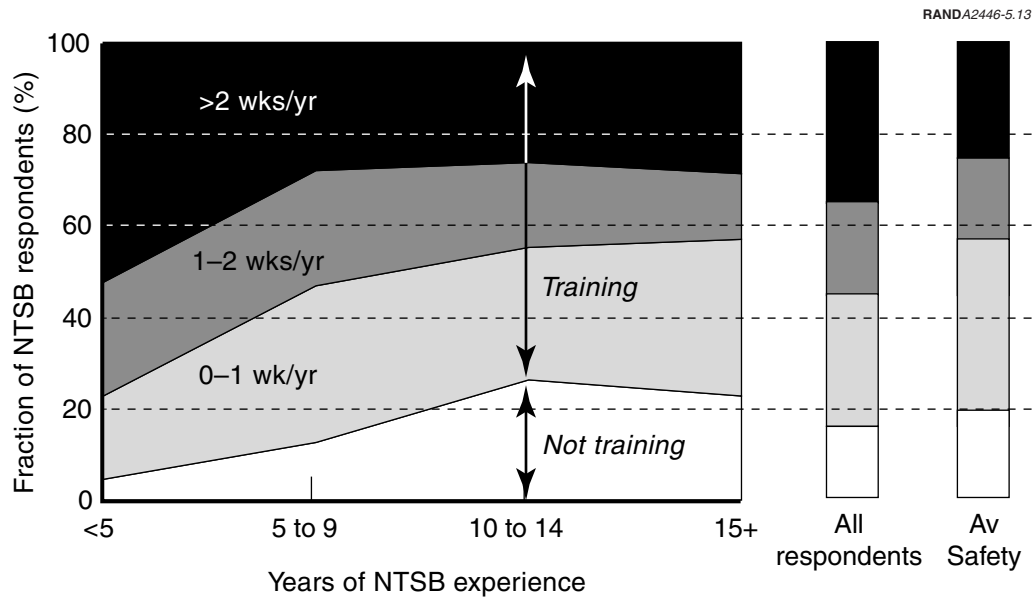


Figure 5.13--Days Spent in Training per Year by NTSB Respondents According to Years of Experience

reported greater levels of training activity than those with more experience. A statistically significant difference existed between training time reported by the least experienced employees and other employees.³⁹

Approximately 25 percent of the most experienced employees reported that they participate in no training whatsoever, while more than half of this group reported participating in training for a week or less per year. These more experienced employees also reported working a somewhat longer workweek.

Levels of reported training activity also varied across organizations. OAS respondents reported less training than staff in other NTSB organizations.⁴⁰ The most pronounced differences were between headquarters-based OAS personnel and all other NTSB employees.

³⁹Differences were statistically significant at the 90 percent confidence level or greater. See Appendix D for a more complete description of these statistical tests.

⁴⁰Differences in reported training activity in the OAS and the rest of NTSB were significant at the 99 percent confidence level.

Data about training activity levels at the NTSB are more meaningful when viewed in a broader context. Table 5.9 compares typical training levels for the airlines and the NTSB. Over time, the airline industry has developed a level of training activity for its personnel that satisfies internal requirements as well as the requirements of the FAA.

Because airline personnel regularly operate flight equipment (70 to 85 hours of flying per month), they acquire a high degree of familiarity with their equipment on the job, which they supplement with formal training. They do not, however, need the accident investigation and project management skills that NTSB investigators require. Therefore, the full spectrum of training necessary for NTSB investigators is not captured by comparisons with the training received by airline personnel. Nonetheless, airline training activities provide useful indicators of the sort of training needed in order to become familiar with aircraft systems and their operation.

Table 5.9
NTSB and Airline Training Activities

Training	Description	Amount of Training
NTSB OAS	Measured, FY93-94	7-9 days/year
	FY96-97 ^a	4-5 days/year
	Self-reported estimates	~6 days/year
Airline flight training ^b	Recurrent	4-6 days/year
	Type rating	20-26 days
	Home study	0.6 days/year
	Flying time	70-85 hours/mo
	Duty time	100+ hours/mo
Airline maintenance training ^c	Senior mechanic	10-12 days/year
	Junior mechanic	20-40 days/year
	On-the-job training	1.5-2 times formal

^aBased on NTSB congressional submittals, various years.

^bLandry, June 1999; Federal Aviation Administration, 1998b.

^cCulhane, June 1999; Utecht, May 1999.

Conversations with flight and maintenance training managers confirm that airlines typically engage in considerably higher levels of formal training than does the NTSB. Characteristically, airlines also offer broad opportunities for on-the-job training, both in the form of day-to-day work experience and through structured training activities.

Flight crew members staying with the same airplane type and crew position typically perform recurrent training once a year for a minimum of four days, with the training split evenly between ground school and simulator training. Crews that fly long haul over water routes and fly low-cycle routes (with fewer takeoff and landing opportunities) may train several additional days per year to satisfy their training requirements.

Flight crew members who are switching to a new airplane type or upgrading from one crew position to another undergo more extensive training. This training lasts at least four weeks and is split evenly between ground school and simulator training. Other training requirements can add slightly more than a week to these totals.

Although accident investigators do not require the same level of flying proficiency as airline pilots, much of the airline training is nevertheless applicable to NTSB needs, including knowledge of flight crew procedures, piloting techniques, aircraft systems operation, interactions with air traffic control, and aircraft flight characteristics. Yet, the *minimum* annual formal training time for an air carrier crew member--four days--is approximately equivalent to the *average* amount of training OAS investigators underwent in fiscal year 1997, including management, investigative, and technical training. Airline crew members moving to a new airplane type or crew position log at least four times more training days than the average OAS staff member logged in fiscal year 1997.

Senior airline maintenance personnel typically undergo two to two-and-one-half weeks of formal training per year, while junior personnel may train two to three times that amount per year. This training includes familiarizing mechanics with aircraft systems and their

operation, a subject area that is also of interest to NTSB investigators.⁴¹

Airlines also use a "buddy system" for structured on-the-job training. Experienced mentors accompany junior mechanics on the job, helping them learn new tasks. The number of hours spent in this type of informal training can be several times that spent in formal training (Utecht, May 1999; Culhane, June 1999).

Collectively, the comparison of training by the NTSB and the airlines suggests that the amount of formal technical training received by the NTSB's OAS staff falls short of industry standards for acquiring and maintaining familiarity with aircraft systems and their operation. In addition, NTSB staff members do not enjoy as rich a set of on-the-job training opportunities as do airline personnel, reinforcing the need for formal training to supplement experience on the job.

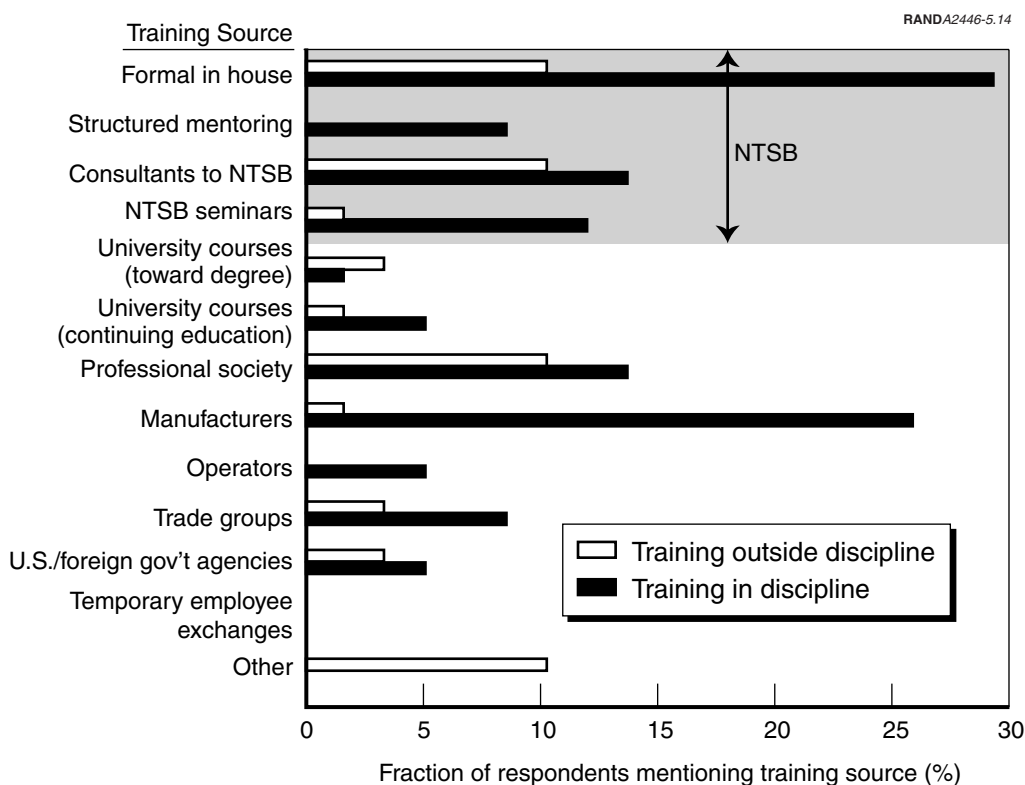
Sources of Training

Most OAS staff training is provided by the NTSB and, to a lesser extent, by aircraft manufacturers.⁴² Respondents to the RAND questionnaire also cited professional societies as a common source for acquiring technical knowledge. Other U.S. government agencies, temporary personnel exchanges, and aviation operators were infrequently cited as sources of training opportunities. Figure 5.14 depicts the fraction of respondents that mentioned each training source.

RAND researchers questioned aircraft manufacturers and airline operators about offering training opportunities to NTSB personnel. Virtually all of these organizations expressed a willingness to allow NTSB participation in the training courses they sponsor for their own

⁴¹Other aspects of maintenance training, such as process training (for instance, learning how to prepare a metal surface for painting), may have less applicability to the skill set needed by NTSB investigators.

⁴²The RAND questionnaire asked employees to identify sources of training beyond their everyday on-the-job experience. According to NTSB staff interviewed by RAND, on-the-job experience is particularly useful in acquiring accident investigation skills; the NTSB also requires that its staff participate in a formal in-house course in basic accident investigation.



SOURCE: RAND Skills and Experience Questionnaire. 58 people responded from OAS Headquarters and Regional Aviation Offices.

Figure 5.14--Training Sources Used for Professional Development by OAS Staff

employees and customers, and a willingness to offer those courses at a reasonable cost.⁴³ The manufacturers and operators interviewed by RAND suggested that their interests are better served when investigations are conducted by informed and skilled investigators. According to the manufacturers and operators, the NTSB rarely takes advantage of these training opportunities.

Manufacturers frequently offer their customers computer-based training (CBT) in operations and maintenance. CBT, which is being widely adopted by the aviation community, may permit some training to be accomplished in home offices without incurring travel expenses.

⁴³One airline manager mentioned that many FAA employees participated in his company's courses at no charge. He believed the same policy could be applied to NTSB employees, but was not aware of any NTSB participation to date.

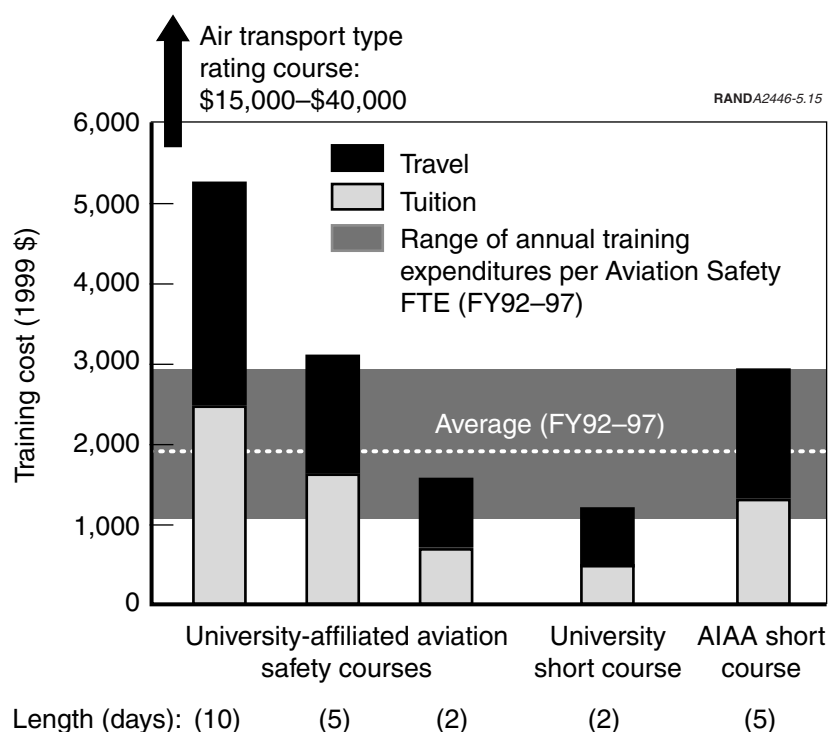
Manufacturers also suggested other possible settings for deriving knowledge about aircraft systems, such as certification review meetings for new aircraft systems (McWha, November 1998).

NTSB staff identified several factors inhibiting the fuller exploitation of training opportunities outside the NTSB. In addition to the most common impediment--heavy workload--employees mentioned the lack of an effective system for communicating the availability of training opportunities, the absence of a clearly articulated policy regarding accepting training from the private sector, limited tuition funding, and course length. No single NTSB organization is responsible for developing an integrated set of information about training opportunities (this issue is discussed in more detail later in this chapter). Because the process is neither centralized nor uniform across offices, training opportunities are undoubtedly missed, as are opportunities to coordinate training across regional and headquarters offices.

NTSB staff members also expressed uncertainty about the rules regarding accepting training opportunities from the private sector, citing the importance of maintaining public confidence in the NTSB's independent status.⁴⁴ RAND discovered that no written policy exists regarding the propriety of accepting private-sector training opportunities. Rather, these situations are resolved on a case-by-case basis by the NTSB General Counsel (Campbell, March 1999). While many staff members expressed no reservations about taking advantage of such training opportunities, staff interviews suggest that the lack of an articulated policy on the matter may contribute to a reluctance on the part of some staff members to explore using outside training.

The NTSB relies principally on its own internal training course to educate new employees in accident investigation techniques, rather than relying on courses offered by several private and university-affiliated schools. As Figure 5.15 shows, tuition and travel costs for these

⁴⁴The Independent Safety Board Act exempts NTSB from rules on receiving gifts in order to assure operating flexibility in the emergency situations in which NTSB operates; 49 U.S.C. §1113.



SOURCE: University of Southern California, Aviation Safety Program; Embry-Riddle Professional Program in Aviation Safety; American Institute of Aeronautics and Astronautics; internal NTSB budgetary records on tuition and travel budgets for training, various years; personal communications with NTSB aviation safety investigators, Summer, 1998.

NOTE: The figure depicts the cost (actual tuition and estimated travel costs) for 10-, 5-, and 2-day accident investigation courses offered by the University of Southern California, a 2-day course on human factors in aircraft maintenance offered by Embry-Riddle, and a 5-day course in conceptual aircraft design offered by the AIAA.

Figure 5.15--Costs of Private-Sector Aviation Training Courses vs. NTSB Funding for Training

outside courses often exceed the NTSB's training budget allocated annually per full-time employee.⁴⁵ Greater participation in outside

⁴⁵Average expenditures for tuition and travel associated with training amounted to about \$1,900 per full-time employee in the OAS between FY 1992 and FY 1997, when expenditures are normalized across all employees in that organization. Aggregate budget records did not permit us to distinguish between tuition and travel expenses for clerical and technical staff. We would expect the technical staff accounted for most of the training expenses. If budgets are normalized excluding clerical workers, the average expenditure per staff member increases by 21 percent, to about \$2,300 per year between FY 1992 and FY 1997. Source: internal NTSB staffing and budget records.

training opportunities would require increases in the NTSB's tuition and travel budgets.

Although additional investments in training are needed, such investments only make sense after the NTSB adopts measures to mitigate its workload problems so that employees will have time to take advantage of expanded training opportunities.

Administration of the Training Process

The NTSB has improved some aspects of its training process since RAND began its study. However, the process still remains largely decentralized and it suffers from a lack of coordination. A brief description of the process illustrates some shortcomings and also some recent improvements.

Training budgets are given to the individual regional offices and headquarters office.⁴⁶ Office directors, in consultation with individual employees, identify training opportunities and decide what course of training is appropriate. While some training opportunities are common knowledge, many are not. There is no agency-wide focal point to identify and catalog training opportunities.

NTSB policy stipulates that new investigators must take certain required courses, such as the basic accident investigation course.⁴⁷ Employees are also required to take courses covering a range of management and administrative topics, including government ethics, sexual harassment, procurement procedures, and other subjects.

Beyond these basic training requirements, however, RAND found no agency-wide standards for training personnel within each job title, although some individual regional offices have laid out course needs for various job titles.⁴⁸ Moreover, training program formats and time

⁴⁶Actual budgets are often not available until several months after the beginning of the fiscal year; therefore, directors estimate available funds from the prior year's budget (Mucho, March 1999).

⁴⁷The chief of human performance in the OAS is also responsible for administering NTSB's basic accident investigation course. This course is generally held off-site because the NTSB's headquarters facilities have traditionally been limited in size.

⁴⁸Mr. Gene Sundeen, Deputy Director, Regional Technical/Investigative Operations, provided course lists, called "Individual Development Plans" or IDPs, which were developed by one regional office

horizons differ from office to office, making it more difficult to conduct strategic planning on training for the agency as a whole.

A new computerized tool that tracks the training activities of individual employees was introduced at the beginning of fiscal year 1999 to replace the tedious manual record-keeping. This tool records an employee's training activities and schedule, but does not serve as an agency-wide repository of information about training opportunities. After each training activity, the employee is required to evaluate the training received. This material is compiled in book form for the NTSB chairman's review.⁴⁹

If fully implemented, the aforementioned tracking tool will help keep tabs on the training activities pursued by individual employees. Nevertheless, the NTSB training process will still have its shortcomings, including the following:

- absence of an individual or department to serve as the NTSB advocate for training, and who will manage the NTSB training program, assist in formulating training policy, and serve as the NTSB's main point of contact on training to the aviation (or broader transportation) community domestically and overseas
- lack of an agency-wide database that catalogs training opportunities
- lack of consistent training plans and training standards across offices
- absence of a clearly articulated policy regarding participation in private-sector training opportunities.

By addressing these shortcomings, the NTSB could materially enhance its training processes and support improvements already being implemented.

for several air safety investigator positions. Periodically, regional offices have tried to coordinate efforts to identify training standards for their staffs, but we found no agency-wide articulation of standards.

⁴⁹As of this writing, this tool is being used by the administrative officer within the OAS. Plans call for it to be used throughout the agency (Case-Jacky, April 1999).

Training Content

As discussed earlier in this chapter, members of the aviation safety community divide the skills needed by accident investigators into three general categories: management, investigative, and technical.

The NTSB views management training as particularly important because of the increasing complexity of organizing and controlling a modern accident investigation. Management training is especially important for IICs because these individuals must coordinate the work of all the parties at the accident scene. As a result, management training has been emphasized in recent years.

Nevertheless, technical training remains critically important at the NTSB. Because investigators must be familiar with the full range of technology associated with modern aircraft operations in order to elicit information about an accident's cause from party experts, technical training is given high priority for investigators who manage party subsets, such as a group chairman for propulsion.

Within the management, investigative, and technical training categories is a wide variety of subjects of interest to the NTSB. In 1997 and 1998, a team from two NTSB regional offices compiled a list of subjects.⁵⁰ This list, provided in Table 5.10, contains both current and proposed new subjects.⁵¹ While some of these courses can be completed in hours or a single day, others require days or weeks of instructional time. Although managers and employees would undoubtedly select a subset of these courses commensurate with an employee's specific skill needs and position, the total list (and the potential instructional time it represents) would dwarf the limited training time currently available to aviation investigators.

⁵⁰This subject list was compiled by Mr. Gene Sundeen, 1999, and Dr. Gary Mucho, Regional Director, Southwest Regional Office (retired). The study topics listed in Table 5.10 reflect a systematic approach to identifying the range of skills and course needs of the NTSB's aviation technical staff. Senior managers can use a similar compilation (updated as needed) as a point of departure for reviewing staff capabilities and designing a set of classes to ensure professional skill development and maintenance.

⁵¹Training in basic and advanced computer skills (not shown) is also provided to NTSB technical staff.

Using the four years of NTSB records assembled for Congress, RAND examined the comparative amount of training that OAS staff received in each of the three major skill areas listed in Table 5.10. Figure 5.16 portrays the results. Technical subjects (which includes the technical, flight training, and operations categories) accounted for more than half of the training. This is not surprising, given that technical knowledge tends to be more "perishable" than management skills or accident investigation skills.⁵² It is surprising that "human factors" training accounted for only 1 percent of all training hours. Given the critical position human factors occupies in many accident investigations, RAND expected this subject area to account for a larger proportion of NTSB training.^{53, 54}

As Figure 5.16 shows, OAS investigators devote about 10 percent of their training time to maintaining pilot proficiency (currency) and qualifying pilots to fly new types of aircraft (type rating). Depending on the arrangements with the training provider, training for a type rating can be one of the most expensive and time-consuming kinds of training. Airline training managers suggested that in less than a week,

⁵²Conceptually, technical training might be further subdivided into training required for skill acquisition and that required for skill renewal. In the former case, gaps in knowledge or the introduction of new technology can create a need for skill acquisition. In the latter case, because accidents occur infrequently, the equipment involved varies from accident to accident, and each accident cause can drive an investigation in a different direction, knowledge retention can be a challenge for accident investigators. Aircraft maintenance managers we interviewed emphasized the constant turnover of technology. For example, the Boeing 777 makes extensive use of digital systems and features a high degree of integration, making it extremely different from many of the older aircraft in the air transport fleet. This kind of turnover in technology creates new training requirements for the airlines (Utecht, May 1999).

⁵³Human factors scientists at the NASA Ames Research Center suggested to RAND that greater interaction between their research staff and NTSB investigators could benefit both organizations (Connors and Statler, September 1998).

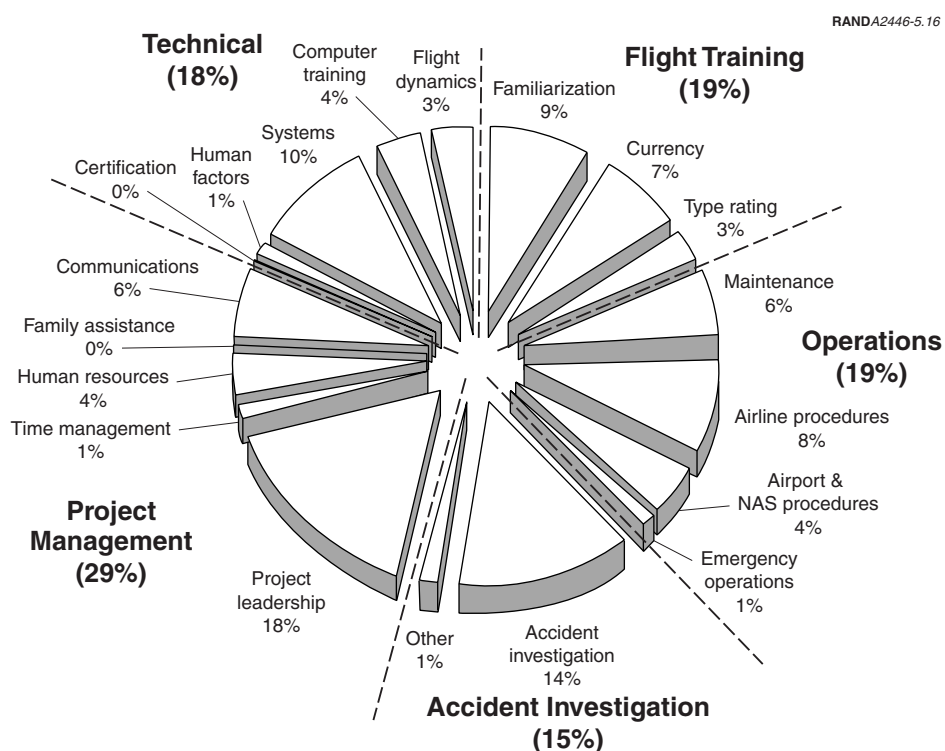
⁵⁴Accidents traditionally labeled as being caused by "pilot error" are increasingly viewed as being caused by design flaws or problems in the human-machine interface. An accurate diagnosis of accidents caused by system error rather than operator error nevertheless requires human factors expertise. See Chapter 3 of this report.

Table 5.10
Suggested Study Courses Identified by Regional Offices

Accident Investigation	Management, Administrative	Technical
Basic accident investigation	NTSB orientation*	Basic aircraft engines
Basic helicopter investigation	Procurement procedures*	Basic aircraft systems
Underwater investigation	Government ethics briefing*	Basic aerodynamics
Accident investigation photography	Office budget procedures*	Glass cockpit technology
Mid-air collisions	Time management*	Composite analysis tech
In-flight fires	Board orders*	Human performance
In-flight breakups	Equal Employment Opportunity (EEO)*	Biohazards
Air carrier incidents	Sexual harassment*	Basic failure analysis
Group chairman training	OPM regulations	Air traffic control procedures
IIC go-team training	Time and attendance	Jumpseat procedures
Tech review panel participation	Budget/accounting practices	FAA regulations
Accredited representative training	Technical conference	FAA refresher course
Board hearing participation	Technical writing	Aircraft operations
Board meeting participation	Project management	Radar plot program
Report writing	Leadership courses	Global Positioning Satellite systems introduction
Media interaction	Conflict management	New aircraft technology
Advanced course	Decisionmaking	Aircraft manufacturing processes
	OPM supervisor's course	Foreign aircraft manufacturing processes
	Problem employees	

*Identified by regional offices as required NTSB training.

SOURCES: Individual Development Plan course lists, NTSB Southwest Regional Office, 1997 and 1998.



SOURCE: NTSB submissions to Congress of training activity, 1993–1994, 1996–1997.

**Figure 5.16--Training Hours, OAS Technical Staff
(Headquarters and Regional Offices), 1993 to 1994**

an individual can get a strong foundation in aircraft systems by using CBT, attending two sessions in a full-motion flight simulator, and occupying the jump seat on operational flights with a line crew for a day (Landry, June 1999).

In the same four-week period now required to obtain a type rating in just one type of airplane, this alternative training approach could familiarize an NTSB investigator with four airplane types. The multiplicity of aircraft types an accident investigator may encounter suggests that the NTSB may want to carefully reassess the current allocation of training hours among the familiarization, currency, and type rating training components.

RAND's review of NTSB operations in light of the emerging aviation environment suggests there will be no diminution in the need for project management and accident investigation skills or general aeronautical knowledge in the foreseeable future. Figure 5.17 presents a notional

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	Potential sources of training									
	NTSB	FAA	USAF	NASA	OPM	Safety bds	Academia	Prof society	Airlines	Contractor
Core skills										
Project management										
“People” skills (team building)										
Organization										
Communications, written and oral										
Accident investigation procedures										
General aeronautical knowledge										
Aviation trend driven skills										
Foreign a/c systems										
Aging a/c failure causes, effects, prevention										
Complex integrated system failure diagnosis										
Human factors and cockpit automation										
Emerging NAS design and operations										
New aerospace vehicle designs and ops										

SOURCE: Interviews with NTSB accident investigators at headquarters and regional offices; survey of emerging aviation trends.

Figure 5.17--Continuing and Emerging Skill Areas for Investigators

summary of the sources of government and private sector training the NTSB could consider if it elects to expand its training curricula. This figure suggests that new alliances with the DOD and NASA could offer extensive training opportunities.

Beyond providing training in the core skills listed in Figure 5.17, the NTSB will need to prepare its staff for the emerging aviation environment (discussed in more depth in Chapter 3). Some amount of training may simply involve expanding upon current knowledge, such as familiarity with foreign aircraft systems and aging aircraft, both of which the NTSB has dealt with to some degree in the past. In other cases, instruction in new systems and operational procedures, such as the NAS architecture and the design and operation of reusable launch vehicles, may require a more substantial investment in training. Potential sources of training on these leading-edge skills cut across virtually every segment of the aviation community.

A workforce possessing the skills listed in Figure 5.17 can help the NTSB meet aircraft accident investigation challenges well into the

next century. However, because of its limited staffing depth, the NTSB will need to determine how its workforce can best absorb those skills. Training staff members across disciplines via formal sessions and by rotating staff members through the various NTSB offices would create a larger number of generalists, giving the NTSB more robust investigation capabilities.

This approach to skill acquisition could supply another important benefit by helping to "grow" new IICs. Staff rotation could also allow IICs to "decompress" from particularly demanding assignments, refresh staff members by varying their assignments, and make the technical and operational communities at the NTSB less insular. In short, the content of training and the means by which it is conveyed to the workforce are equally important factors when addressing staffing and training issues at the NTSB.

CHAPTER 6

IMPROVING NTSB INVESTIGATIVE AND OPERATIONAL PROCESSES

The NTSB is facing a period of dramatic change. The aviation industry, now emerging from a decade of consolidation and defense budget drawdowns, faces growing pressures from an increasingly competitive international marketplace. A more litigious legal environment has raised the stakes for resolving airplane crash liability, and the growing popularity of flying for pleasure, personal transportation, and business continues to feed the seemingly limitless demand for air travel.

Perhaps the biggest development facing the NTSB is the growing emphasis on increased aviation safety as a national policy goal. Because the NTSB provides domestic (and by extension, international) quality control, its mission is closely linked to flight safety. The importance of the NTSB's mission has never been greater, nor has the need for change and forward progress in aviation safety been more profound.

RAND has identified areas in which the NTSB can improve its operations, particularly in regard to staffing, training, and its interaction with the parties to investigations and the broader legal community. These findings are within the scope of this study's original work plan and are reported in Chapters 3 through 5 of this document. During the course of our research, however, RAND collected other findings related to the manner in which the Safety Board conducts its operations, manages limited resources, and controls the massive amount of information required to successfully conclude an investigation. This chapter outlines these additional findings.

The NTSB is an organization with a *proactive* mission and a reactive process. That is, the primary role of the NTSB is to *investigate* accidents, yet the agency's mandate is to *prevent* them. The reactive nature of the Safety Board has evolved from the difficulty of its mission. However, the NTSB has become *too* reactive. Very few of its resources are devoted to taking a more proactive stance related to aviation safety. Its relative inattention to the investigation of safety incidents is the most visible example of the Safety Board's lack of pro-

action. This is not to suggest that the NTSB should shift its priorities from investigating accidents to investigating incidents, but it should direct more resources to examination of the latter. This change alone would strongly reinforce national policy goals related to aviation safety. It would also serve the cause of accident investigation because Safety Board investigators would be more up-to-speed when an accident occurs.

The investigation of accidents and incidents is largely a matter of information management, and the NTSB is in some important ways an information management agency. The NTSB is the main repository of domestic accident information used by other government agencies and many private firms for monitoring and planning purposes. Yet the NTSB does a relatively poor job of managing information. The control and management of information is spread across the organization with little coordination among offices. This complicates the job of conducting investigations and makes outside users less confident of the accuracy of the NTSB's accident data.

The passage of information to and from the NTSB is another area needing improvement. The NTSB's insularity is a by-product of the agency's determination to preserve its independence and remain neutral during the course of accident investigations. Yet, in an environment of growing complexity, working in isolation seems an unwise course of action. The party process is predicated on the notion that the NTSB cannot successfully operate in a vacuum. This is truer today than ever before.

The key to improving the investigation process and strengthening the independence of the Safety Board lies in making the agency less insular while maintaining an experienced staff with unquestioned technical ability. A network of new alliances with other government agencies and academic institutions would allow the NTSB to greatly augment its capacity to acquire and manage knowledge. A less insular environment would also create new training opportunities and encourage NTSB technical staff members to share with the aviation community the wealth of knowledge they acquire at great cost during the course of investigations.

RAND has closely examined the process of developing accident reports. Here, too, the Safety Board could improve the quality of its output and the means for generating it. The process of completing Final Reports puts heavy time demands on NTSB professionals at all levels. Because the workload required to complete reports will likely continue to be heavy, particularly for major accident investigations, the process must be streamlined.

The current process emphasizes reporting over analysis, and NTSB Board members have very little formal opportunity to monitor reports in progress. In fact, Board members have little formal knowledge about major accident investigations until shortly before an NTSB Board meeting is scheduled. Considering the complexity and high stakes involved in a modern accident investigation, this lack of preparation by the Board can cause problems during the review cycle. The limited window of opportunity for Board members to examine the investigative results can lead to breakdowns in the review and approval process.

One way to facilitate the review and approval process is through selective application of peer review. Granting Board members the authority to request a peer review of a draft Final Report when the stakes are especially high and the investigation particularly complex would help ensure that exceptional care has gone into the preparation of the Final Report. In addition, the NTSB could improve the content of its reports by structuring its recommendations around a statement of expected performance rather than focusing on operational solutions.

The core of the NTSB's operation, the accident investigation process itself, should be reexamined in light of the growing complexity of aviation accidents. The current process deconstructs an accident along discipline-oriented lines with separate teams conducting elements of the investigation largely in isolation. This runs counter to the current methods used to design aircraft and the multidisciplinary approach needed to resolve complex system events.

Resolving issues surrounding increasingly complex accidents requires a larger set of tools. The Safety Board's limited technical facilities will likely be strained by future investigations. NTSB laboratories now perform at their operating limit, and the Safety

Board's technical staff already rely heavily on the facilities of party members for testing and analysis. Although the NTSB should not plan to develop expansive research capabilities, it urgently needs to examine its long-range facility requirements.

The management of financial resources in an agency as small as the NTSB is of vital importance. Currently, the NTSB has no way to accurately measure how efficiently and economically human resources are applied to an accident investigation. Because the NTSB relies on the DOT for processing employee payroll costs, it has no means of merging pay and nonpay costs. The development of a complete real-time cost-accounting system would give the NTSB project management capability. Without this capability, Safety Board senior managers cannot assure efficient use of resources nor effectively balance work hours among the myriad activities under way at any given time.

INSUFFICIENT ATTENTION TO AIRCRAFT INCIDENTS

A general agreement exists within the aviation community that studying incident events best illuminates the path to improved aviation safety. More often than not, an accident is simply a failure to detect a preexisting problem. Incidents reveal systemic weaknesses and operational deficiencies, usually long before lives are lost. An accident, particularly a fatal accident, usually occurs following a history of precursor incidents. In turn, the cause of incidents can usually be traced to a larger body of operational data that until recently has rarely been investigated. Taking action based on incidents rather than accidents is becoming more and more critical to improving aviation safety (National Research Council, 1998, p. 29).

In 1997, the FAA recorded 433 major airline incidents, approximately 10 times the number of accidents that are reported to the NTSB.¹ In terms of the amount of attention that incidents elicit from the NTSB, it is a tenth of that given to accidents. As shown in Chapter

¹These data come from the respective FAA incident and NTSB accident databases. The nature of major incidents, which must be immediately reported to the FAA, is defined in 49 CFR 830.5(a).

5, approximately 10 percent of all dispatches made by the investigative staff at NTSB headquarters each year are related to incident events.

At the regional offices, where virtually all GA incidents and accidents are investigated, the number of investigations is even more skewed toward accidents. As shown in Table 6.1, incident investigation accounts for only 3 percent of the total activity in the NTSB's regional offices (National Transportation Safety Board, February 1996). This is not surprising given that very little national attention has been focused on incident trends in GA (National Research Council, 1998, p. 51).

In keeping with its mission, the NTSB is clearly organizationally focused on the job of investigating accidents. Interestingly, the Safety Board's Strategic Plan places accidents *and* incidents as its first stated goal in meeting its proactive safety mission (National Transportation Safety Board, September 1997, p. 3).

Investigating incidents is crucial to the NTSB carrying out its safety mission. Incidents can relay important messages in regard to impending failures of a system. Icing incident reports were routinely filed on the ATR-72 aircraft before a crash that killed 68 people in Roselawn, Indiana, in 1994 (Fredrick, 1996, p. 142). Longitudinal control problems with the Boeing 737 were recorded in a long series of incident reports prior to the loss of United Flight 585 in 1991 and USAir Flight 427 in 1994, accidents that were later found to have been

Table 6.1
1995 Regional Office Activities

	Type of Investigation				
	Major	Field	Limited	Incident	Public
Number of requests	687	2385	1400	90	120
Number of investigations	6	331	1810	67	12
Number of reports	97	1005	1025	60	29

SOURCE: Statistics provided by the NTSB Office of Aviation Safety.

caused by a malfunction in the aircraft's rudder actuation system (Air Line Pilots Association, 1994, p. 13; Brenner, November 8, 1995).²

While they are important harbingers of accidents to come, incidents also *inform* accident investigators of what exactly prompted a crash. This is especially true with serious accidents involving complex systems in which destruction can be total, or with events in which low-fidelity FDRs are encountered. In these situations, related incidents provide vital clues regarding the failure mode at work in the accident. In the future, FDRs with more parameters will speed the task of identifying causal factors. However, familiarity with a history of related incidents will help investigators untangle the cause of major accidents that involve complex systems interactions.

Another set of incidents overlooked by the NTSB lies in the area of aviation security. The NTSB has no clear policy related to the investigation of security incidents, even though such incidents constitute a clear threat to aviation safety. Although major security incidents have come to the attention of Safety Board investigators, no report has been forthcoming in this important area.

Reviews of several investigations have demonstrated to RAND that the NTSB has frequently overlooked the incident history on an aircraft prior to a major accident and investigators have had to conduct extensive research to make up for lost ground. Four principal reasons exist for NTSB's lack of focus on incident investigations:

- **Conflicting Mission.** RAND interviews revealed that many investigators feel that incident investigations clash with the FAA's certification role, thereby threatening the NTSB's independence.
- **Loss of Important Information Paths.** Incident investigations often rely upon information channels that are personal and confidential, and providing information through these channels is optional. In contrast, revealing any relevant information

²Control upsets involving the B-737 occurred throughout the operational life of the aircraft. Most of these events were minor and were traced to problems with a system that dampens slight aircraft yaw movements.

pertaining to a major accident is mandatory. NTSB investigators fear that if they pursue incident investigations more aggressively, their information channels will disappear. Because these information channels also operate during an accident investigation, a loss of rapport with aircraft manufacturers and operators could seriously hamper the NTSB's operational effectiveness.

- **Relevance.** The relative importance of an incident event is frequently tied to the current status of accident investigations. Events that are considered irrelevant to ongoing efforts tend to be ignored while ones that are relevant to ongoing investigations become elevated in importance.
- **Resource Constraints.** As indicated in Chapter 5, NTSB investigator resources are usually heavily strained. In a period of peak workload even a very major incident can be overlooked. Therefore, a qualitative assessment of the magnitude of an event must be performed. Incidents that involve ATC issues, operational factors, a clear threat to safety, or fleetwide mechanical implications are more likely to receive attention. Depending on workload levels and perceived importance, the incident may be passed to a regional office to be examined by a field investigator. In the vast majority of incident cases, the NTSB passes the investigative function to the FAA. At times, of course, the NTSB's workload permits more attention to incidents. At such times, additional investigators are dispatched and the incident can be used as a training opportunity for new personnel.

A lack of resources, combined with the NTSB's cultural focus on accident investigations noted earlier in this chapter, acts to deemphasize the importance of incident investigations. As a result, the NTSB maintains relatively little digital connectivity to the various incident data systems available throughout the world (Federal Aviation Administration, June 1997).³ The Safety Board lacks investigative

³The lack of coordination between aviation accident and incident information has been a long recognized problem. Broader coordination is

support for routinely accessing electronic incident data systems. Without this capability, it is left up to the individual investigator to exercise this function. Because the level of computer literacy varies widely within the investigative staff, critical information can be overlooked.

Many civil aviation incident reporting systems are maintained across the globe, including the following:

- **Accident/Incident Data System (AIDS).** Maintained by the FAA's Accident Investigation Office, AIDS tracks major incidents that are reported to the FAA under mandatory reporting rules. AIDS reports are available via the World Wide Web but the interface is not sufficiently robust to support large-scale incident investigations.
- **Aviation Safety Reporting System (ASRS).** In operation since 1976, the ASRS accepts more than 30,000 incident records each year (National Aeronautics and Space Administration, January 1998a, p. 8). ASRS is a voluntary system maintained by the NASA Ames Research Center. Submittals to ASRS are treated as highly confidential and submitters are protected under FAR §91.25 which ensures that information cannot be used in administrative hearings. The FAA also waives fines and penalties in order to encourage the candid reporting of unintentional errors that cause safety incidents.
- **Flight Operational Quality Assurance (FOQA) systems.** Errors in aircraft operation or minor technical mishaps mostly go unreported in incident reporting systems. FOQA systems capture this operational data, providing a wealth of information with which to closely monitor world aviation. FOQA programs are coordinated through the Air Transport Association's Data Management Committee.⁴ NASA also manages the Aviation

being managed under the FAA's new Global Aviation Information Network (GAIN) initiative.

⁴FOQA programs are operated voluntarily by U.S. airlines. These systems acquire data in much the same way as the aircraft FDR except the data are retained in quick access devices. Because of Freedom of Information Act rules and federal discovery procedures, airlines have

Performance Measuring System (APMS), a joint research effort with the FAA that aims to complement FOQA efforts by providing tools for data reduction, interpretation, and visualization. Work is under way to electronically link the APMS to the FAA's National Aviation Safety Data Analysis Center (NASDAC) (National Aeronautics and Space Administration, January 1998b, p. 3).

- **Accident Data Reporting System (ADREP).** Managed by the Accident Investigation Group of the ICAO and maintained by Britain's Civil Aviation Authority's Research and Development Authority, ADREP follows rules similar to the FAA's for the mandatory reporting of significant accidents and incidents.⁵ As a worldwide data system, ADREP is an important tool for analyzing events that could affect flight safety. ADREP also provides an incident reporting standard that is used by domestic reporting systems, such as Australia's Confidential Aviation Incident Report (CAIR) System, New Zealand's Information Collected Anonymously and Reported Universally for Safety--Confidential Aviation Reporting System (ICARUS-CARS), South Africa's Southern African Aviation Safety Council (SAASCO), Canada's Safety Issues Reporting System (SIRS), Britain's Confidential Human Factors Incident Report Program (CHIRP), the European Union's Confidential Aviation Safety Reporting Network (EUCARE), as well as NASA's ASRS.

The NTSB's use of these resources is slight. For example, Table 6.2 shows one-year user histories for NASA's ASRS system. Safety Board investigations account for 2 percent of the inquiries made to the system.⁶

long been concerned about preserving the confidential nature of FOQA. A recent FAA policy decision to protect confidential data is expected to encourage broader use of FOQA information.

⁵The design and operation of ADREP are outlined in ICAO Document 9156, Accident/Incident Reporting Manual.

⁶Many NTSB investigators expressed concern over the accuracy and ultimate use of ASRS data. ASRS solicits incident reports from all aviation sectors. Individuals who submit information are granted confidentiality and limited immunity in the form of a "waiver of

Table 6.2
Requests to NASA ASRS, 1997

Organization	No. Req.	Organization	No. Req.
FAA	70	Individuals	34
NASA	19	Law firms	8
NTSB	10	Manufacturers	6
Military	9	Professional organizations	34
Other government	10	Foreign organizations	29
Research offices	40	Air carriers	24
Educational offices	8	Media	62
		Other	31
		TOTAL	394

SOURCE: National Aeronautics and Space Administration,
January 1998b, p. 14.

Failure to use the many resources available to accident investigators has retarded progress on many occasions. In one recent major investigation, significant incidents that corroborated NTSB analysis and findings were discovered only when an investigator happened upon a relevant article in an aviation magazine. This discovery triggered a subsequent search of the FAA Civil Aeromedical Institute's Pilot Incapacitation database that uncovered additional, highly relevant incidents.

Because they are immersed in the world of aviation and have an active network of professional contacts, NTSB personnel are usually made aware of major incidents involving specific aircraft designs or operational procedures, despite their not being focused on incidents and not having the benefit of consistent and sustained use of electronic media. NTSB managers and investigators rely on this informal system to

disciplinary action" in order to encourage the reporting of incident information. Many NTSB investigators feel that this encourages an errant proliferation of reports from pilots seeking exoneration, which biases the data and masks more serious incidents. ASRS has, however, proven itself a valuable source of trend information and safety threat warnings.

identify critical incident events that carry the greatest risk to aviation safety.

The general sense within NTSB is that significant problems receive enough attention within the aviation community or from the media to ensure that they do surface. On many occasions, the informal system has worked; serious problems are detected and safety recommendations are issued. But the fact remains that most incident events are not reviewed by the NTSB. Informal background channels have failed in the past, and minor incidents are almost completely ignored. Without a vigorous and sustained analysis effort, opportunities to identify incident patterns are largely lost.

The NTSB's limited response to incidents is not consistent with its proactive safety mission. Whereas accident investigation should remain at the center of the NTSB's core functions, recognizing the importance of incidents and reevaluating their significance within the organization should be a top priority. Increasing the allocation of resources to incident investigation could increase safety investigators' awareness of accident trends. It could also help identify the need for key safety studies, while speeding the job of accident investigation by making the incident record more widely available.

Although additional Safety Board staff resources could permit a broader examination of incidents, this alone will not ensure that a more appropriate balance is achieved. Accident investigators will remain focused on accident events, a proclivity that will continue to limit the importance of incident analysis. Likewise, merely improving access to electronic information is not a sufficient response to this issue. Investigators often lack the proficiency required to manipulate complex data systems effectively; data mining across widely diverse systems is not a job best left to accident investigators.

The NTSB might consider the idea to functionally separate incident analysis from accident investigation. A separate function would have two objectives: to search and synthesize incident records to inform Safety Board managers of urgent safety issues, and to retrieve targeted information in response to accident investigator needs.

The Safety Board must also deal with adopting a new approach to incidents in terms of its organizational culture. This should be done in close cooperation with the FAA to clarify roles, establish rules of engagement, and design the necessary linkages to data systems. Prior recommendations have called for greater NTSB-FAA cooperation on incident investigations related to human factors (Federal Aviation Administration, June 1996, p. 5). Cooperative investigation of incidents and trends could greatly advance safety goals.

MANAGING INFORMATION AT THE NTSB

Information management is an extremely important function at the NTSB. Although the NTSB is a small agency, it is a source of critical safety information for the nation and for the world. As previously noted in this report, the impact of NTSB decisions can be profound. The quality of Safety Board products must be very high and their accuracy must be unquestioned. This assurance depends on the NTSB's ability to acquire, control, and disseminate large amounts of information, in both written and electronic form, in an effective and efficient manner.

This section discusses the decentralized nature of information management at the Safety Board, the seeming lack of attention to managing information, the insularity of the NTSB in terms of acquiring outside information and knowledge, and the potential to improve the investigation process by accessing outside knowledge.

Control and Management of Information Is Decentralized

The NTSB must speak with one voice. However, the assurance of accuracy and uniformity in the messages it delivers is hampered by a fragmented approach to information management and production. Neither the inflow or outflow of information is centrally controlled, nor does much formal coordination exist among components of the organization in regard to information sharing. Information communication within the Safety Board is often incomplete, inaccurate, and hampered by poor coordination. This finding is consistent with a recent review of internal NTSB management and training practices (Ender et al., February 22, 1996, p. 6).

The NTSB views itself mainly as a technical agency. Whereas a great deal of engineering analysis goes into Safety Board activities, the final product is information, primarily in written form. Information management is, therefore, almost as important as the Safety Board's engineering function. The NTSB's technical staff does not generally share this awareness.

In a practical sense, this lack of "information awareness" interferes with many aspects of operations. The public docket, for example, is crucial to tracking the progress of an investigation and is open to any interested individuals. However, important items are not always accurately tracked within the docket and its quality and content are not always reliable.

Information leaks have also been a continuing Safety Board problem. They threaten both the security and independence of the NTSB. Although investigations are ostensibly public information, the Safety Board handles a significant amount of "confidential," "company private," and "trade secret" information. For instance, CVR data and personal information related to deceased crew and passengers must be securely handled, and investigative analyses are not available for review by either the public or the parties.

The family assistance function also influences how the NTSB manages and releases information. Broadening the NTSB's mission to include family assistance has created some tension among staff members. Many investigators were already concerned about the proliferation of accident theories (which has been greatly accelerated by the dissemination of information via the Internet) and view family rights organizations as yet another source of alternative theories. Other investigators are concerned about the need to deliver accurate information to families during the course of an investigation, but fear that the increased visibility stimulates adverse reactions among party members. At the very least, the additional responsibilities that accompany the family assistance program further elevate the importance of information management within the NTSB.

Unquestionably, the proliferation of communication networks has complicated the accident investigation process. The NTSB accepts its

public mandate with an unusual degree of dedication to responsiveness. A mail control process is used to date stamp, catalog, and route the hundreds of pieces of correspondence received during the course of a major investigation. The Safety Board's acceptance of unsolicited theories leaves it open to possible manipulation through the production of excessive or purposefully inaccurate information. The spread of inaccurate information via the Internet has been well documented recently, as has the gullibility of the media (Hanson, May/June 1997).⁷

As the Safety Board's information requirements have grown, spot solutions have evolved in response. In some cases, new organizational elements were created to handle information needs and in others a new function was simply added to existing ones. The chart in Figure 6.1 identifies the various NTSB elements that acquire, manipulate, or distribute information. The figure also shows the major database systems that have been constructed to maintain information. Although these databases enjoy connectivity to a robust LAN/WAN system, they are weakly coordinated.

Decentralized information functions work against the need to integrate information during the course of an investigation. The NTSB must be able to integrate hundreds of relevant facts and data fragments from disparate sources. A chain of evidence must be preserved, making cataloging critically important.

The information gathered during the course of an investigation also generates a wealth of opportunities for later training efforts. Much of this potential is lost because information is not centralized.

Figure 6.1 also depicts the distribution of publication functions. The NTSB produces numerous written products, and their accuracy and quality are crucial. For example, the final Blue Book report is an important milestone for the families of airline accident victims and is a benchmark for litigation and a resource for plaintiff and defense

⁷Internet-based misinformation can not only quickly spread but appear to become factual. For example, in February 1999, Reuters reported that hackers had seized control of four British military intelligence satellites. The story later proved to be erroneous, but many newspapers ran the story without verification.

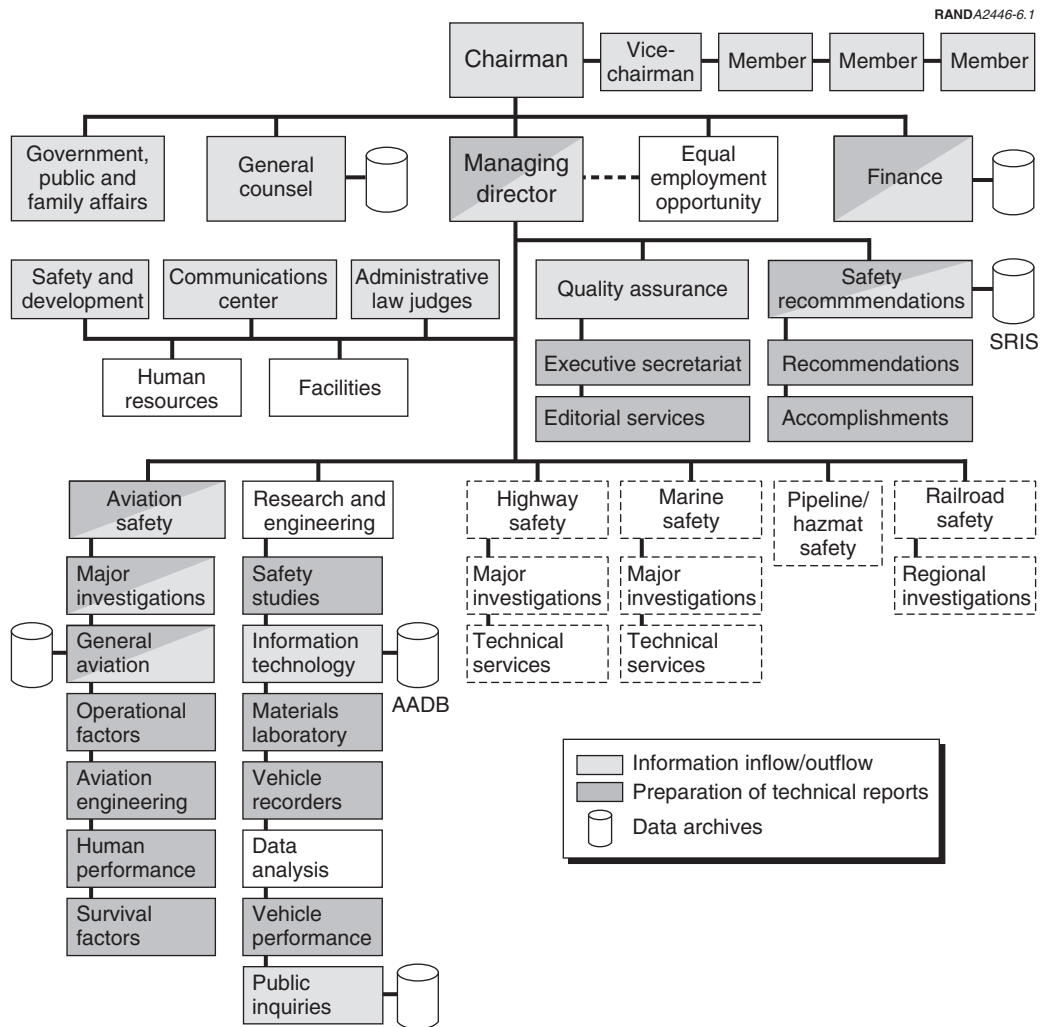


Figure 6.1--Entities Acquiring and Distributing Information Within the NTSB

attorneys alike. Safety recommendations can have an immediate and far-reaching impact on air safety.

Quality, uniformity, and accuracy are difficult to maintain when production of information is spread across numerous areas of the organization. The NTSB maintains no central publications department. Report writing is distributed throughout the organization and each transportation mode is largely responsible for generating its own material.

Graphic representations, a vital part of explaining complex accidents to NTSB Board members, families, the general public, and the

media during sunshine meetings, are also largely distributed by technical offices of the NTSB. In most cases, the responsibility for developing complex graphics falls upon the technical staff. While some of this workload is difficult to avoid (such as the graphics generated by complex computer simulation), the NTSB would benefit from a dedicated staff of artists with expertise in the development of technical graphics.

The editorial review and comment process is also informal. The NTSB's complete editorial policy is contained in a 250-word description of general practices (National Transportation Safety Board, 1998b, attachment 1).

Considering the importance of final information products to the Safety Board's mission, the decentralized approach to producing them is less than ideal. The NTSB's information needs are such that its resources should be realigned to create a higher-end information agency. A notional outcome would call for more centralized information management and production, or at least improved coordination of the operations that are currently distributed across various offices.

More Attention to Database Management Is Needed

The previous section describes how the NTSB is dependent upon the accuracy and uniformity of the information it disseminates. In this section, the quality of the *accident record*, one of the NTSB's most important information resources, is discussed. The accident record supports not only ongoing internal investigations but is heavily used by external agencies for planning and decisionmaking related to aviation safety.

Accident records are vastly important to safety planners, airline insurers, manufacturers, and the traveling public.⁸ Accident information is also crucial to the FAA, where it is combined with inspection and

⁸The U.S. Senate has recommended that safety data be more widely available to the general public (U.S. Senate, 1996). Congress has also expressed concern over the way in which accidents are categorized. In response to this, the NTSB has prepared new methods for classifying accidents.

surveillance data to optimize the agency's mission of aviation system monitoring (GRA, Inc., January 1997, p. 13).

The official record of domestic accident information is the NTSB's Aviation Accident Database (AADB). The AADB is cited extensively and authoritatively throughout the world in the study of aircraft accidents. It is electronically linked to the FAA's NASDAC and can be queried openly through that connection and through the NTSB's own Web site.

The AADB is not the only source of accident information. Australia's BASI, Great Britain's Aviation Accident Investigation Board (AAIB), and other aviation accident investigation agencies maintain similar records. Private organizations, such as England's Airclaims, Ltd., also closely track accident statistics. These alternative sources often correlate their information against the AADB, however, and monitor the AADB closely. Arguably, the NTSB's accident record is the most detailed and comprehensive in the world.

As previously discussed, RAND relied heavily upon the NTSB data records to gain an appreciation of the NTSB's accident investigation workload and output.⁹ Table 6.3 lists the various sources RAND used for analysis, the organizational "owner" of the information, and a qualitative assessment of the accuracy of the information RAND encountered. The NTSB primarily uses its accident and safety recommendation databases as an archive. The quality and content of the data records are generally adequate for this purpose. Nevertheless, they are subject to only limited quality control and often the data entry to update the archives is a low priority.

The AADB essentially functions as a "master index" for the NTSB. Other NTSB databases should be indexed from this record and thereby correlation should be assured. The NTSB should also consider using the AADB to conduct its analytical research. The AADB could be used, for example, to track and study the Safety Board's central finding--the *probable cause* of an event. This important outcome, along with any contributing factors, is generally not used in the study of aviation

⁹Additional discussion of limitations found while integrating disparate NTSB data sets can be found in Appendix B.

Table 6.3
Issues Associated with and Quality of NTSB Data Sources

	Database contents	Source	Issues	Quality
Investigations/workload	Major reports, 1978–current	OAS	Data are not comprehensive of all investigations, have few data fields, and have high number of errors.	Poor
	Recommendations (SRIS)	OSRA	Data are not comprehensive of all investigations, have few data fields, and have high number of errors.	Poor
	Fatal Accident List, 1982–current	Internet	Data are not comprehensive of all investigations, have few data fields, and have high number of errors.	Poor
	All parts, 1962–1974, 1975–1981	ORE	Never validated therefore error rate unknown, many fields intermittently recorded, and no part number pre-1975.	Archival
	All parts, 1982	ORE	Error rate unknown, used different data fields from other databases, did not maintain report date.	Archival
	All parts, 1983–1998 (AADB)	ORE	“Fatal incidents” error rate unknown, many fields intermittently recorded, and report date blank 1983–87.	Good
	HQ Dispatch Log	OAS	Data are not comprehensive of all investigations and have few data fields.	Archival
Resources	Organizational staff levels	HR, CFO	Varying measures of “full time equivalent” staff and no ability to track individual investigation level-of-effort.	Poor
	Organizational budget levels	CFO	Difficult to track “comp time” and no full-cost accounting on per-investigation basis.	Poor

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safety. A report of causal factors would be an important information adjunct for planners and analysts responsible for developing solutions to meet aggressive U.S. aviation safety goals. The use of the AADB as the source of such a report is in keeping with a proactive NTSB.

The importance of the accident record justifies a close examination of information management practices. The need for improvement in this area has previously been brought to the attention of the Safety Board (Lamb, March 29, 1994, p. 153). The NTSB is now working to improve the acquisition and management of information. Efforts are under way to

capture much more information in the event of a Part 121/129 accident and to substantially increase the amount of data related to human factors. The problems in this area are mainly due to a lack of human resources and, to a lesser extent, inadequate equipment. Nevertheless, management's continued attention to this important issue is also needed.

Insularity Inhibits Exploration of Alternatives

The NTSB is a small, self-contained organization that co-exists within a vast collection of designers, builders, and operators that make up the nation's aviation community. However, the NTSB's ties to this community are surprisingly limited.

The insularity of the NTSB is reflected in the few standing alliances and agreements that it has established with government agencies, research laboratories, and academic institutions. The alliance-building movement that has swept through the federal government over the past 15 years has been largely ignored by the NTSB. Table 6.4 summarizes the NTSB's long-term relationships with other federal agencies.¹⁰ The Safety Board perceives this limited set of agreements as being adequate to support its ongoing operations.

The insularity of the Safety Board can be traced to four factors:

- **Interpretation of Its Independent Role.** The NTSB's corporate focus on independent and unbiased accident investigation, in keeping with its mission, discourages openness and cooperation with other agencies.
- **Reliance on the Party Process.** The Safety Board has principally relied on the party process to augment its technical resources during an accident investigation. Evidence indicates that this process has indeed served the Safety Board's mission well. The NTSB staff's confidence in the party system has largely eliminated the need for exploring alternative relationships.

¹⁰The NTSB is currently attempting to fully document the nature of its alliances with other agencies and institutions. Senior NTSB officials, responding to interim RAND recommendations, are attempting to broaden alliances in key areas. Table 6.4 reflects formal alliances that were in place at the time this report was written.

Table 6.4
NTSB Alliances with Other Government Agencies

Agency	Primary Service Provided	Other Roles
Armed Forces Institute of Pathology	Pathology and forensic examination	Yes
Federal Aviation Administration	Rapid deployment flight services	No
	Data collection and analysis	Yes
Federal Emergency Management Agency	Search and rescue	No
Health and Human Services	Pathology and forensic examination	No
Naval Surface Warfare Center	Data collection and analysis	No
United States Coast Guard	Search and Rescue	Yes

SOURCE: NTSB, Office of the Managing Director, May 1999.

- **Staff Pride and Insecurity.** Safety Board staff members pride themselves on maintaining standards of excellence. Most NTSB professionals see the agency as "David" in a land of "Goliaths" and are proud of its technical performance despite its size. However, the professional staff is oftentimes lagging in awareness of technical developments in the aviation field, given the rapid pace of progress in aviation R&D and the limited opportunities for technical training at the NTSB. This combination of pride and insecurity hampers the ability of Safety Board staff to develop mutually beneficial relationships with outside agents.
- **Generalist Nature of the Staff.** One of the great dangers the Safety Board faces is the potential deterioration of the technical staff's professional skills. RAND analysts were frequently told that the best investigators are "generalists" who have enough knowledge in a variety of fields that they are able to ask the right questions at the right time. However, an exclusive focus on multidisciplinary talents can ultimately become detrimental to an employee's professional development.

Lacking an area of specialty, over time a generalist can lose touch with his or her original technical foundation and bypass training and professional symposia that would supply continuing education. Staff work overload compounds this problem. In Chapter 5, RAND acknowledged the importance of training accident investigators as widely as possible. The challenge facing the NTSB is to broadly train a cadre of generalists while ensuring that technical expertise in at least one specialty area is retained.

Developing working relationships with other federal agencies and academic institutions can only serve to benefit the NTSB and encourage the professional development of its staff. Future accident investigations most likely will require expertise that the NTSB, or party members, will not have. In this regard, new relationships are mandatory. The Safety Board will need fresh strategies for identifying opportunities for cooperative agreements and building valuable alliances needed for the future. Strategies such as this are discussed in the next section.

Rapid Access to Outside Knowledge Would Assist Investigations

As defined in Webster's, *knowledge* is a body of facts and ideas acquired by study, investigation, observation, or experience. Maintaining and providing access to knowledge is a primary job of the NTSB. In modern parlance, the term *knowledge management* (KM) typically refers to the process by which organizations acquire and codify knowledge. Like many new terms, the meaning of *KM* depends somewhat on its application. The following definition of "knowledge management" is most applicable to the work of the NTSB:

The identification and analysis of available and required knowledge, and the subsequent planning and control of actions to develop knowledge assets so as to fulfill organizational objectives (Macintosh, May 1996, p. 3).

RAND applies this term to the challenges facing the NTSB of locating relevant *external* knowledge to support its investigative goals, and capturing the extensive tacit knowledge that exists *internally* at the NTSB.

As discussed in previous chapters, the NTSB's size requires that it heavily leverage knowledge from outside sources. The party process is the traditional source of this knowledge and the party system as a central source of information is likely to continue for the foreseeable future. Nevertheless, the following three factors should compel the NTSB to consider expanding its current sources of knowledge and expertise:

- **Increasing Complexity.** As aircraft accidents grow in complexity there is no assurance that party members can deliver the knowledge the Safety Board needs to fully understand the cause of failures.
- **Research Focus.** In a similar vein, increasing complexity will force the NTSB to perform more research in relation to accident investigations. The NTSB is unlikely to see an expansion of its authority to the point that it can match the capabilities of current government, private sector, and academic R&D institutions. It can, however, increase its involvement with such institutions and through new relationships acquire much needed knowledge.
- **Investigation Effectiveness.** Compelling reasons exist for improving the timeliness of Safety Board reports. Investigators must be able to stay focused on establishing as quickly as is practical the cause of an accident. Ready access to outside experts will become increasingly important to ongoing investigations.

A recurrent theme of this report has been the growing importance of the NTSB as a *source* of knowledge. Currently, the Safety Board is primarily a *knowledge consumer*. The NTSB could play an important role in helping to bring about national air safety objectives by recognizing that its staff possesses knowledge relevant to safe aircraft design. But, the Safety Board does little to codify lessons learned from safety investigations, which could be used to educate young engineers who will design future aircraft, or that could contribute to the body of scientific and technical knowledge related to aircraft systems.

In areas such as aging flight systems and fire and explosion research, NTSB investigators and analysts have amassed a substantial

amount of knowledge that is important to aviation safety R&D. Developing even safer aircraft in a world of already exceptionally safe systems requires the establishment of better safety requirements and the expanded use of integrated design teams (Weener, August 1997, p. 4). Supplying NTSB briefings to these teams can help ensure that valuable insights are taken into account at the very beginning of the new aircraft design process.

NTSB training is a two-way street. Safety Board managers should be concerned with not only obtaining better training for their staff, but also ensuring that staff members participate in training others in the aviation community. A regular practice of sharing knowledge gained through event investigations would help make the Safety Board less insular and encourage the formation of new communication pathways.

Figure 6.2 introduces the notion of a "knowledge agent" within the NTSB to perform the KM function. A knowledge agent would serve as a clearinghouse for locating, accessing, and distributing knowledge to professionals within the Safety Board and would identify opportunities

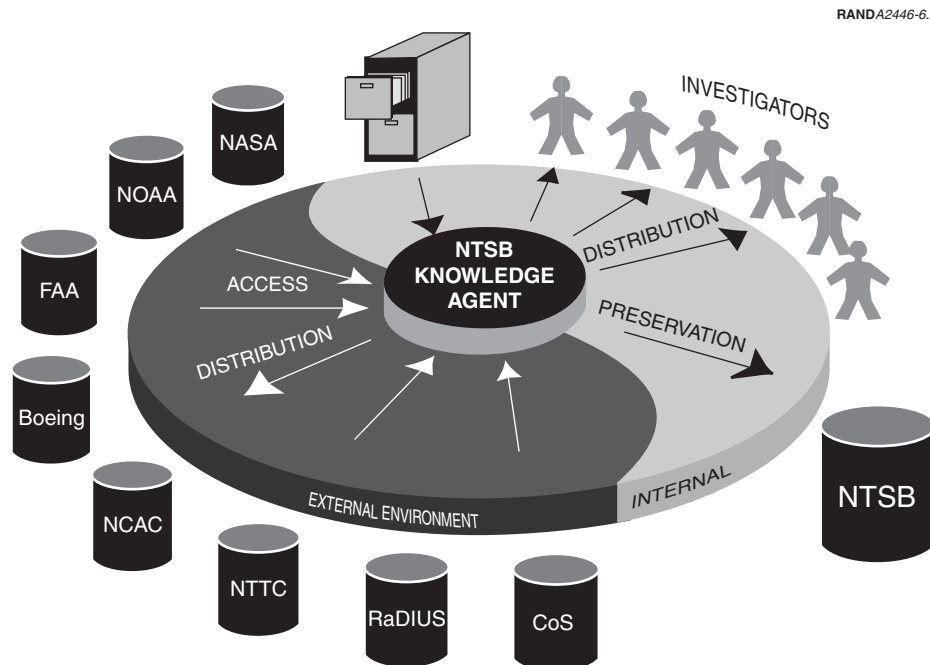


Figure 6.2--Information Access, Distribution, and Preservation Through a Notional NTSB Knowledge Agent

for NTSB analysts and investigators to make key contributions in their technical fields.

A knowledge agent could take advantage of two current developments--the emergence of electronic knowledge-based systems and the steady growth in extramural research, strategic alliances, and cooperative agreements among government, private sector, and academic institutions. As shown in Figure 6.2, knowledge bases are proliferating at a rapid rate. Here are just a few of those shown in the figure:

- **Community of Science (CoS)** is a knowledge system created to assist scientists in operating across discipline boundaries, establishing lines of communications, and locating funding. The COS knowledge system is Internet-based and searchable, linking over 200,000 scientists, 215 universities, leading R&D corporations, and government agencies.
- **National Technology Transfer Center (NTTC)** was established by Congress in 1989. The NTTC provides technology transfer support to researchers in government, industry, and academia. The NTTC monitors federal R&D programs and supports Internet-based searching of research abstracts.
- **Research and Development in the United States (RaDiUS)** was developed by RAND's Science and Technology Policy Institute, with the support of the National Science Foundation. RaDiUS tracks all government R&D activities and resources. RaDiUS is free to government agencies and allows users to quickly search individual research programs and contacts.

These knowledge-based systems and many others like them provide synopses of ongoing research and technology projects in addition to providing contact information to encourage alliance building.

A formal practice of KM, possibly centered on the notion of a knowledge agent, could greatly assist the NTSB's investigative function. This concept would be reinforced by elevating the importance of information management within the Safety Board. Strategies for improving access to and control of knowledge, while improving the quality and uniformity of the information itself, could greatly improve the NTSB's

ability to more effectively respond to complex and challenging accident investigations.

ACCIDENT INVESTIGATION AND REPORTING PROCESSES

Airline transportation accidents garner a disproportionate share of media attention when statistically compared with human and financial losses from incidents involving other transportation modes. It is fair to say that an airliner crash is only the beginning of an accident cycle. The conclusion of the cycle is the NTSB's sunshine meeting in which the findings, probable cause, and final recommendations are presented. This meeting is quickly followed by the release of the Blue Book. All of NTSB's work is synthesized in the Blue Book, which is often the culmination of several years' work.

This section examines the investigation and report writing processes in more detail. It presents notional concepts aimed at streamlining current practices. This section also discusses the creation of safety recommendations and examines the adequacy of Safety Board facilities to support future accident investigations.

Final Report Preparation Process Should Be Streamlined

The sudden loss of hundreds of people generates intense public attention. For the aviation industry, however, an accident's impact lies in the Blue Book and its power to influence the production and sales of aircraft. A direct and very tangible socioeconomic connection exists between the outcome of an accident investigation and the aviation marketplace. Aerospace products generate hefty revenues and, as shown in Table 6.5, they continued to be a major positive factor in the U.S. balance of trade.

The sale of transport category aircraft accounts for more than half of civil aerospace exports. While remaining strong, the contribution of all U.S. aerospace exports to the U.S. balance of trade has been generally declining as a percentage of total merchandise exports since the early 1990s. During this period, military exports have grown slightly, signaling a loss of U.S. dominance in civil aircraft markets. This is due in large part to emergent international competition from Airbus and other manufacturers. Today, the international market can

Table 6.5

Import/Export Balance for Civil Aerospace Products, in \$Millions

Year	Aerospace Exports	Aerospace Imports	Aerospace Trade Balance	Overall U.S. Trade Balance
1988	26,947	9,087	17,860	[118,526]
1989	31,111	10,028	22,083	[109,399]
1990	39,083	11,801	27,282	[101,718]
1991	43,788	13,003	30,785	[66,723]
1992	45,018	13,662	31,356	[84,501]
1993	39,418	12,183	27,235	[115,568]
1994	37,373	12,363	25,010	[150,630]
1995	33,071	11,509	21,561	[158,703]
1996	40,270	13,668	26,602	[170,214]
1997	50,374	18,134	32,239	[181,488]

SOURCE: Aerospace Industries Association, 1998, p. 115.

support only a single sizable U.S. commercial transport aircraft enterprise, the Boeing Commercial Aircraft Company.¹¹

Increasingly, safety is a major component of the aerospace industry's economic performance. A major airline accident can quickly erode confidence in the performance of an aircraft, destabilizing its market position. Repeated accidents and incidents involving a particular type of aircraft can devastate the market position of its manufacturer. In the increasingly competitive aviation marketplace, such opportunities are quickly exploited. The history of the DC-10 is illustrative.

The United States dominated the post-war aviation economy, a reign that was mostly unchallenged until the emergence of Europe's Airbus consortium in 1970. Several experts have linked the loss of U.S. dominance in international aviation markets to the safety performance of the DC-10 aircraft (Golich, 1989).¹² The Airbus consortium as a

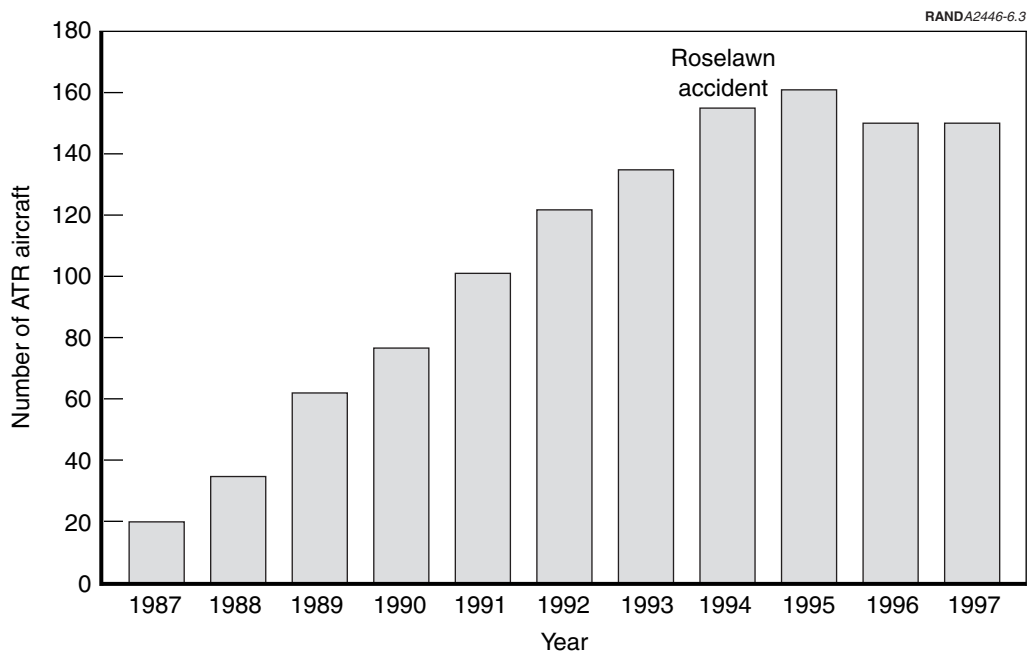
¹¹Boeing acquired the McDonnell Douglas aircraft manufacturing operation in 1996. Lockheed withdrew from the commercial transport sector after the market failure of the L-1011 transport.

¹²Built by the McDonnell Douglas Corporation, the DC-10 suffered several major accidents and repeated safety incidents associated with its design. The 1974 crash of a Turkish Airline DC-10 in Paris and the 1979 loss of an American Airlines DC-10 in Chicago killed 346 and 258 passengers, respectively. The Paris crash was traced to a failure of the aft cargo door, a mode that had been preceded by a 1972 incident in which an American Airlines DC-10 suffered a cargo door failure without a loss of life. The Chicago crash was attributed to improper airline

manufacturer of large civil transport aircraft today builds very popular airliners, supplying planes for a significant portion of the domestic airline fleet purchases (interestingly, the DC-10 and its competitor the Lockheed L-1011 were originally called "Airbuses").

As mentioned in Chapter 3, an accident can have a powerful impact on sales, as demonstrated by the 1994 Roselawn, Indiana, crash that involved the European Aerospatiale Avions de Transport Regional (ATR) 72 aircraft. Following the accident, the historically strong sales of the aircraft declined as it became less popular with U.S. operators, as shown in Figure 6.3.

Clearly, major aircraft accidents can have a significant impact on the U.S. economy. Chapter 3 of this report argues that whereas accidents will likely be fewer in number in the future, they will increasingly bring into question design factors and the performance of individual



SOURCE: Aerospace Industries Association, *Aerospace Facts and Figures*, 1992, 1995, and 1997, Table of Active U.S. Air Carrier Fleet. Data include both the ATR-42 and -72 variants.

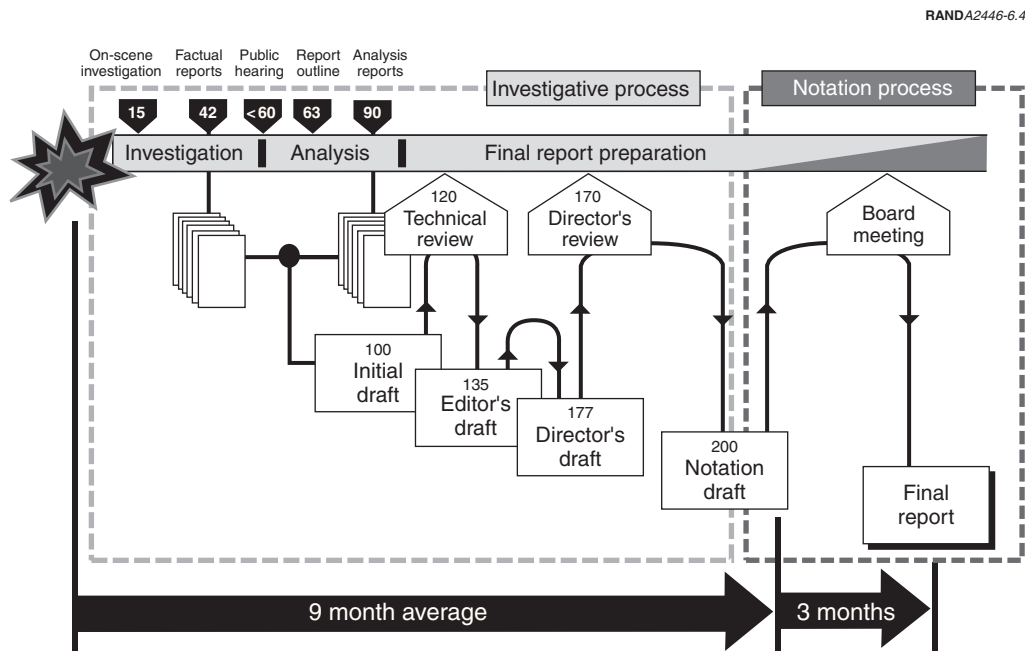
Figure 6.3--ATR Aircraft in the U.S. Air Carrier Fleet

servicing of the engine mounts, but design deficiencies were also noted as contributory.

aircraft types. Therefore, the amount of attention paid to NTSB reports will likely grow. This added attention will come not only from manufacturers and litigators, but also from the traveling public, for whom safety is an increasingly important topic.

NTSB personnel often undervalue the importance of their role and the need for assured quality in their products. The current process of developing and reviewing final reports does not necessarily reflect the importance placed on them by the external community.

Figure 6.4 outlines the process used by the NTSB to produce an Final Accident Report.¹³ The figure depicts a baseline in which the



SOURCE: NTSB Board Order #2B (expired); NTSB Board Order #300; NTSB *Accident Investigation Manual*.

Figure 6.4--NTSB Investigation and Report Process

¹³The actual time line for production of Final Reports was specified in a now outdated process description document for report preparation, NTSB Board Order No. 70 (dated March 16, 1998). This was later replaced by Board Order No. 300 that contains much less specificity in the time line. The current NTSB *Accident Investigation Manual* references the outdated Board Order No. 70 and was therefore used to create Figure 6.4.

Final Report is to be completed within one year from the date of the accident. If it is clear at the outset that an investigation will continue beyond the baseline period, the IIC must obtain approval for an extended investigation.

Several elements in this timeline warrant attention. Most important, in the baseline investigation the time available for accident investigation and analysis is approximately one-third of the total period. The process of writing, editing, and gaining approval therefore takes twice as long as the investigation itself.

The process for bringing a Final Report to the NTSB Board creates a tense interface between the technical staff and Board members. Investigators and technical group leaders are responsible for delivering factual and analytical reports to the IIC who then drafts, or oversees the drafting of, the Final Report. The draft is prepared in accordance with guidelines established by the ICAO (National Transportation Safety Board, November 22, 1995; International Civil Aviation Organization, July 1994). An editorial review process refines this draft before it is distributed to the NTSB directors. The edited Final Report is logged in for formal review by the Board through a tracking procedure known as the Notation Process.

Theoretically, Board members gain official access to the draft Final Report only after the document enters notation and a hearing date has been selected for the sunshine meeting. In practice, this rarely occurs. Quite naturally, Board members want more than a few weeks to digest a highly technical report that contains complex arguments. Therefore, the process outlined in Figure 6.4 is often circumvented as NTSB Board members seek to obtain early drafts of the factual and analytical reports.¹⁴

Many members of the aviation community and representatives of victims' families suggested to RAND that party members exert disproportionate influence over the preparation and content of Final

¹⁴An internally conducted review by the Report Quality Committee of the NTSB noted that improved communication between the technical staff and the Board members was needed and recommended that direct interaction between the staff and the Board be planned prior to the sunshine meeting (National Transportation Safety Board, February 1998, p. 3).

Accident Reports. Some observers contend that parties directly manipulate the NTSB's technical staff. The RAND analysis found no indication that such direct intervention occurs.

Few outside observers appreciate the extent to which internal debate occurs among technical staff and the aggressive challenges to analysis and findings that occur within the NTSB as a whole during a major accident investigation. However, there are other ways for parties to exert influence. In a major investigation, the technical staff is consumed by the focus on the final review and obtaining NTSB Board approval. The technical staff is motivated by the fear that outside forces will exert influence on Board members and unravel the analysis, findings, and recommendations through aggressive questioning before the report reaches the sunshine meeting. From the perspective of the technical staff, the essentially "political" Board is an easy target for manipulation through suggestion.¹⁵

To understand why reports for a major investigation can take so long to complete, one has to appreciate the fact that the NTSB technical staff is committed to leaving no stone unturned prior to proceeding to notation. Whether or not the theories of cause are believed to be plausible, each theory must nevertheless be reviewed, and counter-arguments must be prepared, before the sunshine meeting. RAND did find evidence that when the stakes are high, external stakeholders sometimes endorse theories of cause that even they do not believe, with the knowledge that doing so will likely lengthen the Safety Board's investigation. The proliferation of accident theories also is potentially useful in later litigation procedures.

¹⁵At least three Board members are appointed based on "technical qualification, professional standing, and demonstrated knowledge in accident reconstruction, safety engineering, human factors, transportation safety, or transportation regulation" (49 CFR 1111[c]). In practice, however, Board members cannot be expected to demonstrate proficiency in the many areas of technology and operations discussed in a major accident report. They are not in a strong position to conduct a technical review and can be forced to either accept or reject the entire report based on high-level assessments that must be concluded very quickly.

Members of the aviation community have called for the NTSB to open its analytical phase to party participation. This would not serve the best interests of the NTSB's independent investigation. Isolation from party review is essential during the analytical phase because it provides the NTSB time to formulate and test hypotheses that are not considered or supported by party members.

Isolation from the NTSB's analytical phase does not, however, prevent party members from tracking the progress of an investigation. NTSB's limited resources require frequent use of external resources, often owned by party members, to conduct engineering tests and evaluations. The Safety Board, in some cases, also retains experts and consults with other agencies. These activities demonstrate a clear pattern of NTSB activities to the careful observer. Information leaks from the NTSB provide additional clues on the direction of an investigation. It can be safely assumed that party members are fully aware of the direction of an investigation.

In summary, the process of completing a Final Report requires gathering together a technical staff suspicious of the Board's motives and who will attempt to keep Board members in the dark as long as possible, the NTSB Board members themselves who must confront extraordinarily complex arguments without benefit of adequate preparation, and, indirectly, party members who are aware of findings and recommendations and are possibly motivated to introduce contrary theories. Out of this process, the NTSB must deliver a final product that reflects unbiased thinking, evenhandedness, and technical proficiency--and it must be *probably* right.

The report review process needs a major overhaul. The process should be refined to promote thoroughness by the technical staff while removing elements that lead to behavior that may impede the timely completion of reports. To achieve these objectives, RAND suggests that the NTSB consider the selective application of peer review in the report preparation and review process. While many within the Safety Board may perceive peer review as a diminishment of the NTSB's independence, a properly crafted peer review process would accomplish the following goals:

- Provide an important incentive for the technical staff by setting a standard of high achievement.
- Assure investigators that work products will be judged on the basis of technical merit.
- Assure Board members that analyses and findings have withstood a rigorous and unbiased technical review.
- Strengthen the independence of the Safety Board and provide additional evidence to the public that its mission is being fulfilled with vigilance and thoroughness.

Peer review has been endorsed throughout the federal government as a mechanism for improving the quality and timeliness of products (U.S. General Accounting Office, June 1996; U.S. General Accounting Office, September 1996b).¹⁶ It was noted that the NTSB was prompted by earlier suggestions to improve report quality and the Safety Board agreed to distribute completed reports to the EAA, AOPA, and FAA for their review (NTSB, March 29, 1994b, p. 26).¹⁷ RAND was not able to establish whether such post-completion reviews resulted in substantive contributions to NTSB product quality; in any event, no modifications to the production process were discernible.

In addition to considering the addition of peer review, the Safety Board should develop a means for providing greater insulation from outside influence. In many respects, the evaluation of an accident report mirrors the federal procurement process and the activities of contract Source Evaluation Boards. The NTSB should evaluate the similarities between these processes and the possibility of moratoriums on access to Board members during the period when an Accident Report is reaching notation. A refined report generation and review process employing such tactics will simplify and improve the timeliness of Accident Reports.

¹⁶Kostoff, 1997, provides a thorough review of the application of peer review to federal programs.

¹⁷In particular, Recommendation 44 of Volume II of the 1994 NTSB proceedings document deals with this issue.

Tension over NTSB Findings and Recommendations Will Likely Increase

Theory and practice are easily confused in the entanglements of accident investigation. The NTSB, as well as the various entities that preceded it, were founded on an ideal of truth-finding and truth-telling.

In theory, the NTSB enjoys statutory insulation from matters related to the economic performance of aviation stakeholders. Its deliberations are mostly private and its findings highly public.

In practice, the NTSB operates in a quite different world. Safety Board investigations can have a major impact on aviation economics worldwide. The NTSB's influence extends into the foreign policy arena, such as in cases involving aircraft from foreign manufacturers or in matters affecting overseas operations. In practice, the NTSB operates in a world of technical imperfection, with limited human resources and limited technical facilities.

Perhaps the most readily apparent concession to practicality is the goal of establishing "probable cause." When initially established by the Air Commerce Act of 1926, aviation accident investigations were thought unlikely to yield definitive results; as a result, an investigation was meant to identify only the "probable" cause (Miller, Winter 1981).¹⁸ The Safety Board's recommendations should exhibit a similar concession to practicality. While the NTSB must not be swayed from energetic fact-finding and analysis, it must exercise caution to prevent overextension of its recommendations.

A never-ending tug-of-war, albeit a productive one, exists among managers and staff within the Safety Board regarding their view of recommendations. One end is supported by a *functional viewpoint* that understands the volatile nature of the aviation economy and favors caution in exercising NTSB authority.¹⁹ The other end is supported by a

¹⁸Miller provides an excellent review of the early history of aviation accident investigation.

¹⁹Exercising prudence in recommendations has been very important to Safety Board managers and the organization to ensure that "each proposed recommendation is carefully evaluated to make sure that it is practical, feasible, and capable of being implemented." (Sweedler, March 29, 1994, p. 78).

visionary viewpoint that favors setting high standards, and pushing the aviation community to attain higher levels of safety.²⁰ Both perspectives share a focus on safety and an appreciation of the potential impact of Safety Board recommendations, and each viewpoint is tempered by a desire to ensure NTSB credibility and thereby maintain its independence. No viewpoint has ever been victorious, but as leadership of the NTSB Board has changed, the balance has shifted, at times dangerously, toward one end or the other.

Under close public scrutiny, the NTSB's recommendations must be made in full recognition of two myths--the myth of risk avoidance and the myth of uniformity of system safety:

- **The Myth of Risk Avoidance.** Through constant reassurance, air travelers have come to believe that aircraft manufacturers and airline operators avoid risk at all costs. In fact, risk is a managed resource and is calculated and traded throughout the aviation system. An aviation company balances two separate but interrelated goals--its economic performance and the safety of its products (Flight Safety Foundation, January/February 1994, p. 1). Certainly all stakeholders in the aviation industry have demonstrated a dedication to safety that has contributed to a remarkable reduction in accidents and incidents. Aircraft are not, however, designed with *risk avoidance* in mind; risk must be traded against the practical measures of economic operation. Only in extraordinary conditions can an engineering enterprise afford to avoid risk at any cost. Examples of such situations do exist, including the human space-flight program, the development of nuclear power plants, and the manufacture of hazardous biomedical materials. In the realm of aviation,

²⁰Many NTSB recommendations have "raised the bar" on transportation safety. For example, in 1969 the Safety Board recommended that the legal age to purchase alcoholic beverages be raised to 21 years. This recommendation, issued at the state level, initiated a national debate on teenage drinking and driving and the subsequent passage of stricter laws. Another example of NTSB leadership was a 1972 recommendation calling for the installation of GPWS in large transport aircraft. This call, for what was at the time a technology only nearing maturity, accelerated development efforts.

however, risk is minimized within the boundaries of affordable acquisition and operating costs. An airplane is an imperfect device characterized by design considerations that must balance cost, performance, and risk.

- **The Myth of System Uniformity.** A second myth is that of safety consistency within the aviation industry. Manufacturers, airlines, and support organizations do not operate with equal levels of safety. Yet, variations across the industry must be tolerated by federal regulators, industry representatives, and insurance underwriters--indeed all members of the aviation community.²¹ This tolerance promotes the appearance of uniform safety across the industry in order to achieve the vital high level of confidence among the traveling public (Wald, March 16, 1997; Hedges, Newman, and Cary, June 16, 1998; Barnett et al., May 1998).

An airspace system in which risk is not avoided but instead is managed, and safety is nonuniform, is the reality into which NTSB recommendations are cast.

NTSB recommendations cross a broad spectrum, from simple advisories to better inform operators to complex directives that can alter the design of operating fleets. Priorities can also range from long-term fixes (Class 3--approximately 5 percent), to moderate priority modifications (Class 2--approximately 86 percent), to high priority changes that require urgent action (Class 1--approximately 9 percent).

Tensions surrounding NTSB recommendations increase the more they suggest fleetwide design implications and the greater their urgency. System complexity will continue to increase rapidly and accident investigators will likely delve into issues related to the design of aircraft systems more and more. For this reason, the NTSB should

²¹Some within the aviation community thought that the FAA would take a tougher stand if the agency's long-standing "dual mandate" to simultaneously regulate and promote the industry was removed. The mandate was in fact removed in 1996, yet the FAA has not assumed a more aggressive regulatory posture. Even as a regulatory body, the FAA remains constrained by the reality that it must oversee an industrial sector that is critical to the health of the national economy and is at the same time battling within a fiercely competitive global arena.

anticipate heightened tension surrounding its recommendations and act to ensure that the process of formulating and reviewing them is bolstered to maintain a balanced perspective.

Dealing with issues that can potentially influence the design selections made by aircraft and system manufacturers, as well as issues related to the original certification of new aircraft types, has always been a challenge for Safety Board investigators, and this situation is likely to intensify. In cases in which the investigation points to problems associated with the design of the aircraft, the NTSB will inevitably encounter trade-offs made by engineers when they designed the aircraft.

In such cases, the NTSB must resist the temptation to issue recommendations containing design solutions, which it has neither the tools nor the expertise to develop. Positing design solutions is especially dangerous for the NTSB, as it implies that investigators have conducted some amount of cost/benefit analysis that they are legally precluded from conducting. The NTSB can and should issue recommendations that establish the *level of performance* expected of a system to ensure safety. Borrowing language from performance-based contracting models could be particularly useful in this regard.

Augmenting the party process with a broader set of strategic alliances, as discussed earlier in this chapter, would also help ensure an outcome of balanced and reasonable recommendations. Although the party process will continue to be crucial to successful NTSB investigations, it may prove insufficient in complex, high-stakes investigations. In these cases, it is quite possible that the original equipment manufacturer may not understand a failure mode and therefore may not be capable of resolving technical issues.

The NTSB must also ensure that a strong linkage exists between recommendations and probable cause findings. The nature of probable cause statements varies widely in NTSB Final Accident Reports. When the NTSB wishes to focus attention on a particular safety issue, a single statement of cause is often used. This prevents any straying from the focus of the investigation and what is perceived to be the central safety threat. Approaches to formulating probable cause findings have

varied under the changing Safety Board leadership. In practice, however, events rarely have a single cause. This is especially true of very complex accidents. In some cases, the aviation industry has been slow to accept safety recommendations because the recommendations were not associated with a cause listed in a Final Accident Report (Hagy, March 29-31, 1994, p. 166).

The NTSB is guided by a doctrine of reasonableness that has well-served the interests of the American public. With attention to reinforcing the process in the face of increasing tensions, the NTSB should be able to maintain balance by issuing recommendations that lead to steady and stable improvements in aviation safety.

Future Accidents May Challenge NTSB Investigative Methods

The NTSB's core function centers around the activities of its investigative staff. Before discussing ways to improve the structure of these investigations, it is important to first distinguish between investigations occurring in the field (regional offices), which focus on GA accidents, and those staffed from the Safety Board's headquarters offices.

As detailed in Chapter 2 of this document, both types of investigations are built on the structure of appointing a lead investigator.²² In the field, the Air Safety Investigator (ASI) dispatched from a regional office usually works alone and investigations do not receive extensive support from the OAS in Washington. Field investigations are also usually much smaller in scope, making only occasional use of the Safety Board's headquarters-based laboratories facilities.

The field ASI is arguably more independent and "in charge" than a comparable IIC dispatched from Washington, D.C., to a major investigation. Parties have long complained to the NTSB about inconsistencies in the process of investigations, particularly in the regional offices where classification of accidents and the methods used

²²The authority of the lead investigator is specified in 49 CFR 831.8, which gives the investigator broad lateral authority during the course of the investigation.

to investigate them vary widely (McCarthy et al., March 29, 1994). Although a standard process has been defined by the Safety Board, in practice its application varies according to the size and complexity of an accident, and even a particular investigator's style.

While field investigations are important, RAND's analysis focused on major accident investigations being controlled from NTSB headquarters. The meaning of the term "IIC" is elevated when an accident involves an airliner in which many lives are lost. The NTSB naturally reserves its most senior investigators for such events. The NTSB has invested heavily in the maturation of a small cadre of highly trained, versatile, and talented individuals who form what is essentially a "front guard." These individuals form the Major Accidents Division within OAS. Currently, there are seven senior accident investigators in the Major Accidents Division.

The traditional NTSB investigative model, called here the Discipline Team Model, is shown in the left-hand diagram in Figure 6.5. In this model, a rotation process places available IICs (as well as an NTSB Board member) on call in the event of a major accident. When an

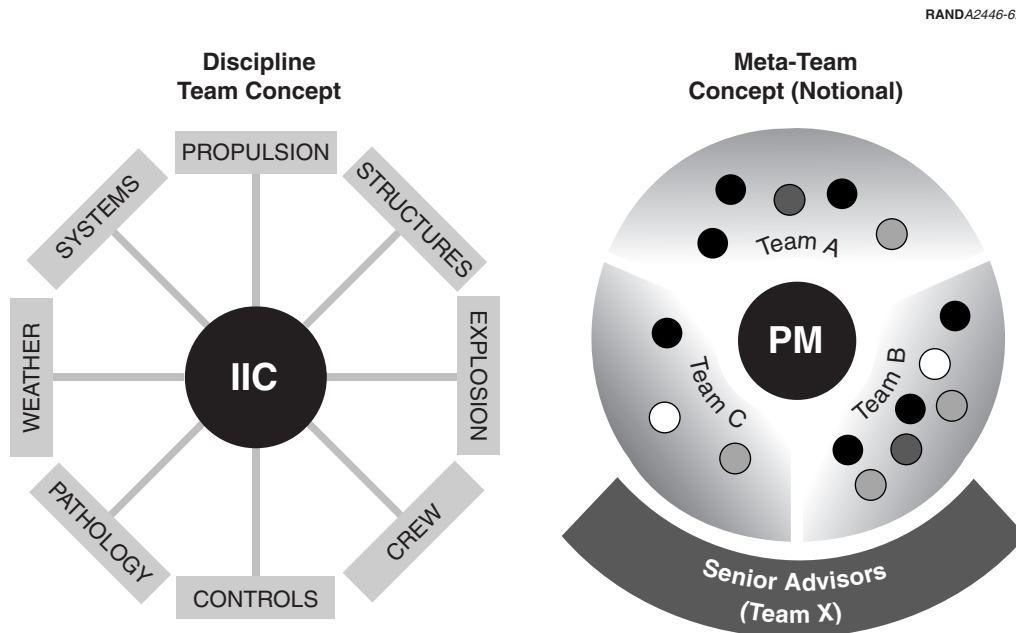


Figure 6.5--Discipline Team Model vs. Notional Meta-Team

accident occurs, the NTSB's dispatch time is rapid. *Go-teams* are formed and are on scene usually within 12 hours. The pressures on an IIC during a major accident investigation are enormous. A senior IIC must quickly manage an array of go-teams operating in parallel and reporting daily, respond to media inquiries, manage the accident scene itself while ensuring that all critical information that will later be needed is captured, and coordinate party member actions and inputs. Most important, the IIC is looked upon to establish the tone of the investigation. Decisions made at the accident site can determine the direction of the investigation, and changing direction later can be accomplished only with great effort.

The implementation of the Discipline Team Model is especially important. Go-teams are led by NTSB investigators and are composed of both Safety Board personnel and party representatives. These teams are charged with examining the accident from the *perspective of their technical expertise*. The IIC controls the interaction of these teams and the integration of team inputs. There is usually little interaction between the teams, formal interchanges being limited to daily debriefings led by the IIC during which team leaders summarize progress.

Viewed from the outside, the IIC appears to be the control point, even for a major investigation. In practice, however, responsibility for the progress of a major investigation can shift quickly from the IIC and the Major Investigation Division to a higher level of management in the OAS. Several factors determine how fast and to what extent IIC responsibilities roll off following the conclusion of the on-scene portion of an investigation:

- **Anticipated Magnitude of Investigation.** It is usually possible to quickly assess the level of analysis required for an investigation and to estimate whether a single individual is likely to succeed in adequately controlling it.
- **IIC Capacity and Experience.** A complex accident investigation requires extensive coordination and mastery of diverse subjects. If it is estimated that the investigation will require an exceptional breadth of skills, OAS managers will often feel the need to augment the IIC.

- **Staff Workload.** OAS managers are usually facing staff overload problems, and IICs from the Major Accident Division are particularly vulnerable because of their senior status and limited numbers. Although it is difficult to prevent work overload, OAS managers attempt to prevent burnout among senior IICs and try to build a reserve for possible emergency responses.

Although the IIC continues to play an important role in a major accident investigation, the position can be operationally secondary to an informal structure of sub-elements orchestrated at the OAS directorate level. At the sunshine meeting it is often not apparent who led the investigation and little mention is made of the IIC at all.

The process of shifting investigative authority has several drawbacks. Foremost, an attempt to control several major investigations simultaneously places enormous management burdens on the OAS directorate office. It is also difficult to assess who is really in charge of a major investigation without concluding that management authority is ultimately held solely by the OAS director. A good deal of tension exists between the Major Investigations Division and the directorate office, which stems from feelings that on a major investigation the title "IIC" is figurative. In addition, the stochastic nature of aircraft accidents causes the OAS directorate to alternate between calm and crisis. The worst case scenario--several major investigations simultaneously in process--can bring about a protracted period of crisis management that seriously erodes staff interrelationships and productivity.

It is likely that the NTSB will continue to face a retinue of accidents similar in type to those that investigators have faced in the past. However, the Safety Board should anticipate accidents of unprecedented complexity and system-level interrelationships. The investigation of the crash of USAir 427 is a good example of this class of event. In short, the NTSB must organize, train, and equip its staff, and also seek external relationships that support higher-order investigations. These investigations will have attributes not unlike applied research projects. Solving complex accidents, such as accidents

representing aircraft conceived and built in a structured team environment, will require that the Safety Board consider stepping beyond the Discipline Team Model.

Alternative investigative models should seek to clarify and strengthen the practice of managing the investigation, ensure that diverse expertise can be brought to the Safety Board when needed for as long as it is needed, and encourage an awareness of systems complexity and associated team cooperation. This last point is especially important. A central weakness of the Safety Board's traditional investigative method is that it does not encourage multidisciplinary analysis, testing, or evaluation. The resolution of complex failures might well be better accomplished through multidisciplinary teams, an integrative and cooperative problem-solving model applied in the design of modern aircraft (Sarsfield, 1998).²³

Figure 6.5 presents a notional model for accomplishing these objectives. The Meta-Team Model, shown in the figure, is constructed to encourage team interactions in conjunction with centralized *project management*. Such a model does not preclude the need to dispatch go-teams to the accident site to accomplish recovery, interviewing, and fact-finding. It does, however, seek to quickly assemble the go-teams into analytical groups organized to pursue resolution of failure scenarios as expeditiously as possible.

Little research has been conducted on teams operating in engineering environments or on scientific problems. The majority of research on team dynamics has been conducted in relation to business planning and management, oftentimes consisting of artificial constructs and using model participants (in many cases students). Studies to date have shown, however, that technical teams have to be carefully constructed in order to be successful.

Foremost in a technical environment is the desire for creative tensions within the team, tensions that draw out the inquisitive, probing natures of scientists and engineers (Pelz et al., 1966, p. 7). The fuzzy border shown for the meta-teams in Figure 6.5 is meant to

²³This refers to the practice of utilizing Integrated Product Teams in aerospace design.

relay a built-in "looseness" that is important to its success. Looseness here means *autonomy*, a sense of allowing a team to alter or refine tactics and methods to independently achieve its objectives (Nowaczyk, February 1998, p. 8). Team autonomy does not remove the need for clear technical and programmatic objectives set by NTSB senior managers.

Teams operating under high-stress conditions do, however, excel when technical autonomy is combined with a strong project leader (LaBarre, June 1996, p. 77). Operations aboard an aircraft carrier provide a good example of the advantage of flexible team structures. Despite hierarchical organizational structures, considerable flexibility is provided to personnel operating on the ship's deck to form the best solution to accomplish safety and performance goals (Pool, June 1998).

Another feature of the meta-teams concept is the fluidity in the makeup of the team. Team leaders should be able to identify skilled experts and, through pre-negotiated mechanisms, access them for a period of time needed to meet team objectives. The various shaded areas shown within the elements of each meta-team in Figure 6.5 reflect this diversity; it is unlikely that any team would be composed solely of NTSB personnel. Meta-teams reflect a need for rapid access to knowledge and strong communications skills and capabilities. Currently, the NTSB's ability to quickly identify potential team participants is not sufficiently robust to support the notion of meta-teams.

A recent development that might advance the ability of the NTSB to accomplish the kind of operations envisioned by the meta-team is *virtual team* building. A virtual team environment is one in which documents, specifications, drawings, memos, briefings, analytical data, and models can be shared by professionals who are geographically dispersed.

Teleconferencing and e-mail are already used extensively to coordinate accident investigations. Communication via telephone alone is insufficient to convey complex technical data during an aircraft accident investigation (Baum and Huhn, 1997, p. 10). Virtual teams offer a distinct advantage given their increased speed and agility, their ability to leverage expertise and integrate geographically dispersed organizations, reduce travel costs, and minimize lost time. Such concepts are gaining popularity in many sectors of the aerospace

industry. NASA, for example, operates a virtual team environment called the Virtual Research Center (VRC) that allows "badged" personnel direct access to online project management systems.²⁴ Virtual teams are not a quick and easy solution to the challenges associated with an accident investigation. Leading a virtual team requires unique skills and technology must be carefully selected to match specific applications (Duarte et al., 1999).²⁵

The notion of a meta-team is built upon strong project management skills. Although training in project management practices has not been applied extensively within the NTSB, the training data in Chapter 5 show that these skills are being taught to investigative personnel. The central limitation in employing project management practices at the NTSB is the lack of cost accounting practices that permit sufficient visibility into how resources are being expended. Such capabilities are required for true project management to work effectively.

The responsibilities of a meta-team would be manifold. The most important function would be to quickly formulate and implement a work plan for the investigation. The PM would have to integrate the factual data from field work, party recommendations, and incident reports and, with the support of senior NTSB advisors, form a set of accident failure scenarios. These scenarios provide the basis for meta-team formation. These meta-teams should be structured to:

- provide sufficient size to examine all aspects of a failure scenario
- comprise NTSB staff, government and academic experts, and consultants
- interact with party members on an as-needed basis (party discussions should flow through the PM to ensure that team requests for information, analysis, and testing are coordinated)
- solicit nondisclosure oaths from external participants pledging that they will not discuss ongoing results

²⁴The NASA VRC is available online at moonbase.msfc.nasa.gov.

²⁵Duarte provides an excellent treatise on the design and implementation of virtual teams.

- produce a team report, delivered to the PM, outlining the failure scenario the team formed, the test plan used, the analytical methods used to resolve the scenario, test results and error potentials, and team conclusions.

Meta-teams would be led by NTSB investigators responsible for performing an initial assessment of the scope of work. Each team leader would create a staff and financial plan for the investigation. The PM would then integrate meta-team resource requirements, estimate requirements for reserves, and submit requests to the NTSB's chief financial officer (CFO). Immediate funding should flow from the NTSB's emergency fund and would depend on having sufficient reserves to quickly procure the necessary staff and facilities. Finally, the PM would control the level of investigation to ensure that failure scenarios are pursued to sufficient detail to meet Safety Board requirements of probable cause and to prevent analysis beyond the point of efficacy in this regard.

The use of senior advisors, shown in Figure 6.5, is another important element of the notion of employing meta-teams. In the figure, the term "Team X" is borrowed from a model in use at NASA's Jet Propulsion Laboratory (Smith, January 1997). The central concept here is to employ an agency's most senior staff across a body of parallel initiatives without committing them wholly to any specific activity.

The IICs of the Major Accidents Division are some of the Safety Board's most seasoned and best trained experts and would be an ideal source of Team X expertise. Employed in an advisory capacity, current IICs would not be "lost" to a major investigation. Instead they would be available to support all ongoing investigations and to consult to outside organizations to support the goal of improving international air safety and air accident investigations. They would also be available to coach younger employees, helping to groom a new generation of safety investigators.

The notion of meta-teams is one of many possible approaches to streamlining the NTSB's investigative processes to help it contend with increasing accident complexity and the anticipated continuous growth in workload. Although the Discipline Team Model has served the Safety Board

well, there are signs that it is growing difficult to control, requiring heroic efforts on the part of investigators and managers to accomplish the desired outcomes. Sustaining such a stepped-up pace is not a tenable long-term approach for meeting the requirements of modern air accident investigations.

Inadequate Testing Facilities Undermine NTSB Independence

The NTSB conducts investigations and trains personnel using facilities, tools, and equipment that can only be characterized as modest. Figure 6.6 depicts the four principal laboratories that serve the generic requirements of multimodal accident investigations and the types of tools they employ. These facilities, although sufficient up until this point, are unlikely to adequately support future requirements.

As noted in Table 6.4, the NTSB maintains limited relationships with other federal agencies. Fire and combustion studies for several major accidents have also been conducted in cooperation with the FAA

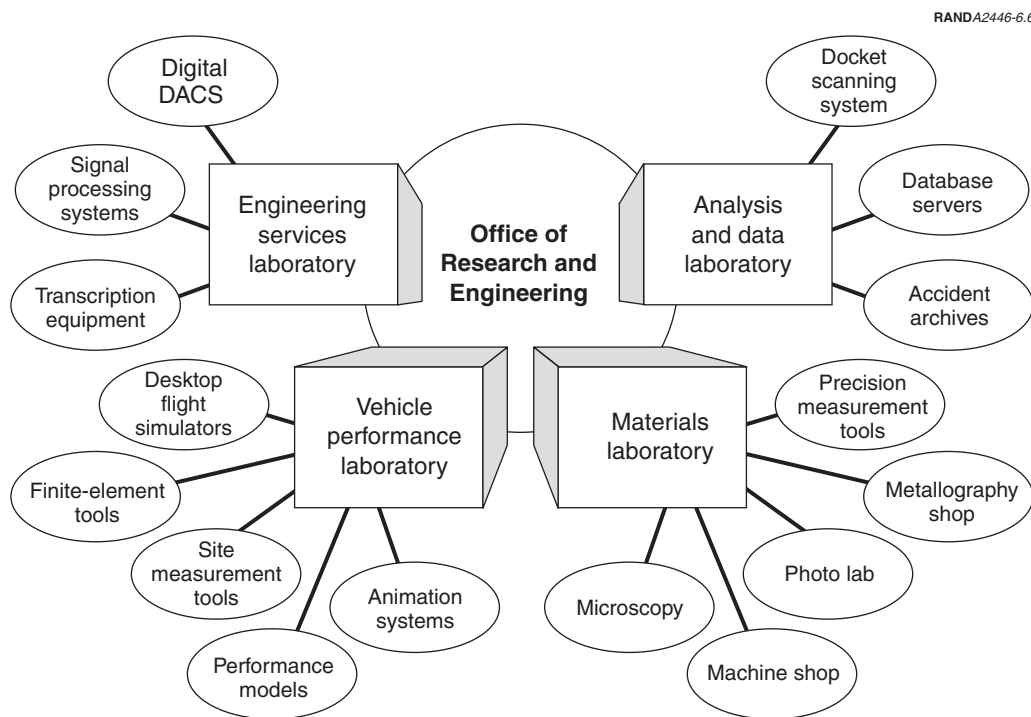


Figure 6.6--NTSB's Four Principal Laboratories

Technical Center's Fire Research Branch. Forensic toxicological analysis related to aircraft accidents is provided, for example, by the FAA's Civil Aeromedical Institute (CAMI) at no cost. Most of this support from other government agencies is provided at no cost to the NTSB. The Safety Board also maintains a limited set of contracts with private laboratories for fire and explosion testing, as well as X-ray and advanced spectrographic analysis.

The floor space for the four NTSB laboratories shown in Figure 6.6 totals approximately 4,000 square feet, no larger than the size of a large private house. In addition to aircraft accident investigations, these facilities support the investigation of rail, marine, highway, pipeline, and hazardous material accidents.²⁶ The NTSB office and laboratories are used only to a small degree for training. In-house training is limited to a two-week indoctrination course for new employees. These courses are taught in rental facilities by senior NTSB investigators. For more advanced training, the NTSB relies almost exclusively on outside institutions.

Aerospace professionals can obtain accident investigation training from several sources. The Air Force Safety Center's (AFSC's) Crash Laboratory at Kirkland AFB, New Mexico, operates a 29-acre facility devoted to training accident investigators. The facility includes exhibits of destroyed aircraft duplicating the original accident scene, and its laboratories contain failed components and systems.

The Crash Laboratory complements a network of AFSC classroom and conference facilities for initial and ongoing training of investigators. A smaller academic facility is located at the Embry-Riddle Aeronautical University's Center for Aerospace Safety Education in Prescott, Arizona. This eight-acre facility includes the Robertson Aviation Accident Investigation Laboratory, a hands-on facility for investigator training containing several reconstructed crash scenes. The University of Southern California operates the Aviation Safety Program, which offers

²⁶As part of the ongoing investigation of the TWA Flight 800 crash, the NTSB leases an additional 80,000 square-foot facility from the city government of Riverhead, New York. This facility houses the reconstructed B-747 aircraft as well as providing temporary storage of victims' personal effects.

classroom programs in aviation accident investigation. The Boeing Corporation maintains extensive in-house training capabilities and also utilizes military and academic training facilities.

For actual conduct of accident investigations, government agencies such as NASA, the FAA, and the Air Force, in addition to large private companies, maintain facilities that vastly exceed the capabilities of the NTSB. These organizations benefit from engineering complexes designed for research and development that can be used to support accident investigations.

It can be argued that the NTSB can continue to utilize the facilities of others when needed, either on a cost-reimbursable basis or through no-cost alliances and agreements. However, there are several reasons why the NTSB should rethink the long-term adequacy of its current physical resources:

- **Reconstruction.** Increasingly, investigators must reconstruct major parts of crashed aircraft to obtain sufficient information about failure mechanisms. If enough wreckage is available, reconstruction can greatly assist the task of understanding complex failure modes. Reconstruction is even more important for accidents involving aircraft that contain FDRs with limited parameters. Reconstructing even parts of a commercial aircraft requires a good deal of floor space and usually high-bay facilities.
- **Simulation.** The NTSB has built an excellent simulation capability based on workstation software models. The importance of these simulations was demonstrated during the course of the USAir Flight 427 accident investigation. This accident involved the near total destruction of the aircraft, a limited parameter FDR, and the interaction of complex aircraft systems. Simulation was an essential ingredient to understanding the accident and supporting the investigative findings. The importance of simulation will certainly grow as a result of this investigation, and future requirements for fidelity and accuracy will likely outstrip the capabilities of workstation-based solutions. Full-scale programmable flight simulators

provide the necessary fidelity. These cabin simulators model actual flight-deck systems allowing more accurate flight reconstruction and an improved ability to understand human-machine interactions. Software changes allow them to mimic the performance of a variety of aircraft. With an adequate library of aircraft models, at least for every transport category aircraft, the NTSB could rapidly model flight profiles with greater accuracy. Cabin simulators are widely available in government and industry. NTSB investigators would probably make heavy use of such a capability, rendering it a cost-effective tool to have in house.

- **Generic Test Tools.** Another important factor is the flexibility offered by in-house (or readily accessible) test tools. No-cost or leased facilities often have to be scheduled well in advance and priorities rarely favor the outside user. NTSB's requirements are driven by critical air safety concerns. An excessive dependence on outside resources threatens the ability of the Safety Board to respond quickly.²⁷ The NTSB's independent status can also suffer. Many of the facilities used during an investigation are, of necessity, owned by party members. Devices such as flight controls test rigs (iron birds), protoflight and prototype equipment, and system integration labs are impossible to obtain from a source other than the manufacturer. The independence of the Safety Board is strengthened, however, when sufficient resources are quickly available to support testing at critical junctures. A carefully selected set of generic test tools, such as hydraulic test stands, electrical power systems, and avionics testbeds, could support rapid response experimentation.

Expanded technical facilities would also provide new opportunities for in-house technical training. Facilities, like the ones described

²⁷The size of the current Emergency Fund does not support a strategy of securing rapid access to facilities. Currently a \$2 million reserve, this fund has typically been quickly oversubscribed when a major accident occurs.

earlier, serve a dual role--they greatly expand the tools available to investigators and they provide the equipment necessary to train. A flight simulator, for example, is a powerful tool for the parametric study of factors that could have caused an accident. However, simulators are primarily designed to train flight crews.

For reasons detailed in Chapter 3, future accidents will require the NTSB to conduct more research to discover causal factors. This has implications for the Safety Board's organizational culture, and it also determines the kinds of tools the NTSB will need to successfully accomplish its mission. It has been reported that the Safety Board is contemplating some form of facility upgrade (McKenna, February 8, 1999, p. 75). It is not clear, however, that the NTSB has conducted, or intends to conduct, a comprehensive review of its facility requirements in support of such an initiative. The NTSB's Office of Research and Engineering (ORE) does monitor near-term requirements, attempting to ensure that testing and evaluation is accomplished cost-effectively.

The Safety Board has not attempted to analyze the possible impact of emergent investigative trends, or to undertake a long-range plan for facilities planning. RAND did not detect any attempt to merge training and investigation requirements into a cost-effective facilities solution. The requirements for training and for investigative services are handled separately, bypassing consideration of any options that could present lower cost solutions.

Industry professionals interviewed by RAND were unanimous in their agreement that the Safety Board currently operates with insufficient resources. A modest expansion of facility capabilities seems a wise investment in strengthening the capabilities of the NTSB. The NTSB should, however, thoroughly investigate all means of acquiring needed capabilities and ensure that facility plans are comprehensive, responsive, and cost-effective.

LACK OF COST ACCOUNTING DATA INHIBITS MANAGEMENT OF INVESTIGATIVE RESOURCES

It became clear during the course of this study that resource limitations impact many, if not most, Safety Board operations and processes. It was equally apparent, however, that lack of adequate

accounting information precludes effective management of the human resources that the NTSB does have at its disposal.

Managers within the Safety Board have little information with which to make planning decisions regarding the utilization of staff resources and properly manage staff workloads. Without such information, *internal* cost/benefit trade-offs cannot be made and the allocation of resources to ongoing accident investigations can quickly become unbalanced.

Figure 6.7 shows the current tracking of salary and nonsalary expenditures within the NTSB. With the existing accounting practices, working-level managers lack sufficient feedback. Time and attendance reporting at the NTSB is completed via electronic spreadsheets. No attempt is made to track employee time against individual accident numbers, although such numbers are assigned for other tracking purposes immediately upon notice of an accident or incident event. The NTSB relies on the processing of salary information through the DOT's Integrated Personnel Payroll System (IPPS). Nonsalary accounting is handled through a financial accounting system (FinAst) managed in-house by the CFO's office.

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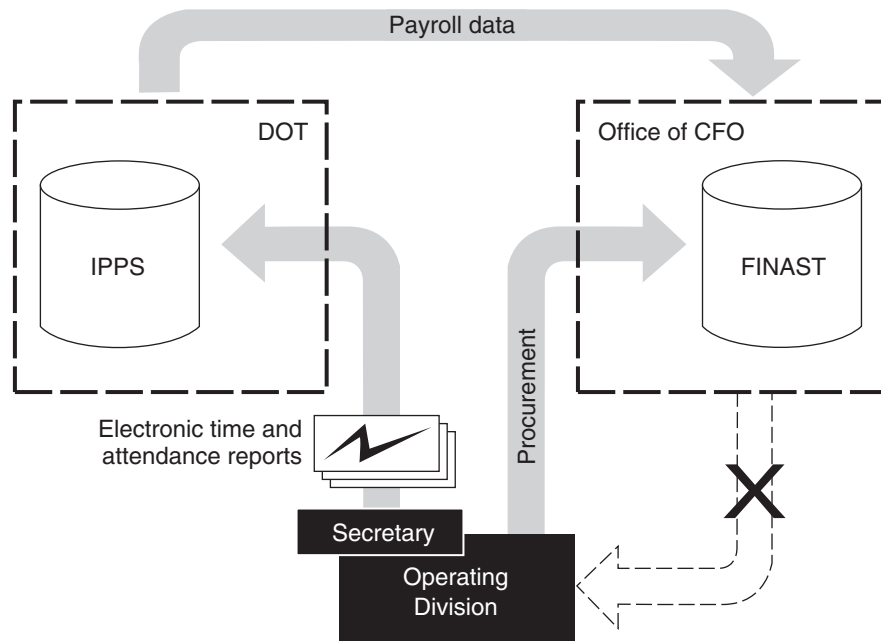


Figure 6.7--NTSB's Open-Loop Accounting System

The IPPS and FinAst databases allow the NTSB to report to congressional oversight offices. As such, these databases have much greater fidelity and are more carefully controlled than the Safety Board's accident and recommendations databases, which are archival in nature. Although the financial systems are tightly controlled, and spending on *purchases* for individual accident/incident investigations is tracked, at present no method exists to merge pay and nonpay expenditures into a single spending profile.

Repeatedly, recommendations have focused on the NTSB's lack of a full cost accounting system. As early as 1980, a General Accounting Office (GAO) analysis of Safety Board planning and management criticized NTSB internal budget practices that prevented the tracking of activities or programs (U.S. General Accounting Office, May 28, 1980, p. 6). The report targeted internal practices in the area of program control, concluding that, "the [Safety] Board has no formal plan for systematically reviewing its programs." At the same time, a Heritage Foundation report also noted the dearth of program analysis at the Safety Board, and noted that its lack of adequate accounting practices inhibited its internal planning abilities (The Heritage Foundation, October 31, 1980, p. 4). Although the Safety Board has experimented with a more complete accounting system, one that combined pay and nonpay costs associated with a given accident investigation, it has not yet made a long-term commitment to such a system.

Accident investigations are akin to projects of varying size and dimension. NTSB managers need the tools with which to manage individual investigations as if they were projects. The old adage "you can't manage what you can't see" can be aptly applied to current Safety Board practices. The NTSB continues to evaluate internally managed time and attendance reporting and the use of project-style practices. Establishing a practice of full cost accounting will require a significant investment of resources by a team from across the NTSB, including the ORE, OAS, the CFO, and the other modal offices of the Safety Board.

Finding the necessary resources among an overloaded staff will be very challenging. Without the necessary financial and human investment,

however, it is unlikely that any new system would provide sufficient fidelity and utility to contribute to improved performance. The development of improved resource management tools, especially in regard to monitoring employee workload, should receive the highest priority.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This chapter draws conclusions about the key challenges currently facing the NTSB and makes recommendations to help preserve and enhance the NTSB's ability to fulfill its crucial safety mission. The major issues are summarized and common threads that run through each topic or study area are restated and amplified.

CONCLUSIONS

Although the NTSB has a need for additional resources and improvements to its internal systems and processes, the historical constructs upon which the agency was founded are basically sound. No significant alterations in the law are needed to provide for the changes that must be made. The party process--the central organizational mechanism supporting air crash investigations--should continue to exist as an important source of vital information for the Safety Board.

When the economic stakes in an accident are especially high, as they increasingly are, a greater risk exists for the party process to falter. In circumstances such as this, it is only prudent that the NTSB be prepared to augment the party process by securing technical expertise through alternative avenues.

The equivocal nature of the party process historically has been balanced by the NTSB's technical leadership. If the party system places the integrity of the investigative process at risk, the skills and experience of the NTSB staff must compensate for any imbalance. In this regard, any potential erosion of the NTSB's base of expertise and any challenge to the strength of its professional staff are of great concern. The current heavy workload significantly impairs the ability of the technical staff to receive the training necessary to maintain technical proficiency and exercise leadership in accident investigations.

It is unlikely the NTSB's heavy workload will suddenly lessen. The Safety Board will be called upon to resolve increasingly complex accidents and do so in the face of mounting scrutiny and rising economic

stakes. The NTSB must also adopt a more proactive posture with respect to accident prevention by studying *incidents* more carefully, both to support its own investigative processes and to advance national aviation safety goals.

The NTSB will also become an increasingly visible aviation safety leader around the globe, supporting foreign investigations and playing a strategic role in reducing the risk of aircraft fatalities worldwide. Therefore, although the number of major airline crashes may diminish as the United States pursues an aggressive aviation safety agenda, the NTSB's workload will at best remain the same and most likely will rise.

It is clear that the NTSB needs additional human resources and facilities. The current heavy workload limits the ability of the technical staff to exploit training opportunities that are available to them. An augmented workforce could provide greater flexibility, which in turn would support increased training. Changes in the administration, frequency, and amount of training are also vitally needed.

The NTSB's current engineering laboratory facilities are barely adequate and are not sufficiently up-to-date given the complexity of the systems being analyzed. When in-house resources prove inadequate for a particular investigation, the NTSB has tended to rely on facilities and equipment supplied by parties to an event. This reliance on support from parties increases the risk of conflict of interest and threatens the Safety Board's independence, especially in high-profile cases in which NTSB leadership is most crucial.

Increased resources alone, however, will not ensure a renewed level of responsiveness and excellence at the NTSB. The Safety Board will need to adopt changes to its operation and processes while introducing a modern project-oriented information management system to efficiently and effectively manage its resources. Such changes are a prerequisite for monitoring the progress of other new initiatives.

The challenge is clear: The NTSB must substantially revise its practices, more closely manage its resources, and break out of the cultural insularity that is widening the gap between its staff and the rest of the aviation community. The NTSB leadership must make the requisite improvements while continuing to ensure the independent nature

of its investigations and maintain the authority of its professional staff. As the NTSB embraces the need for change and tackles the many challenges that lie ahead, sufficient resources must be made available to the NTSB to support the needed modernization.

RECOMMENDATIONS

Uniquely structured as an independent investigative agency not empowered with any regulatory authority of its own, the NTSB relies on the credibility of its findings and recommendations to persuade other governmental agencies, and powerful commercial enterprises, to accept and implement its conclusions. Excellence is demanded, and the recommendations outlined in this chapter emphasize the need for a Safety Board that is a model of technical and managerial leadership.

A recurring theme in these recommendations is the NTSB's "insularity." The NTSB has become a very isolated agency, a dangerous trend that could increasingly alienate the Safety Board from the aviation community. The NTSB depends on this community for cooperative investigation support and the collaborative efforts needed to ensure the safety of the National Airspace System. NTSB senior management must focus on breaking away from this pattern of insularity. The Safety Board must demonstrate a greater spirit of cooperation with outside entities, without jeopardizing its independent status. The NTSB must be *an open and impartial agent* pursuing the cause of aviation safety.

Another continuing theme of this study is the need for greater efficiency. Under the glare of media coverage and heightened public interest, the NTSB must marshal an array of resources and expertise, and do so from within the confines of a small agency with a tight budget and limited staff. The NTSB must demonstrate that it can operate with the utmost efficiency. With its enormous mission and limited resources, the NTSB simply has no other choice.

RAND's recommendations are divided into eight proposed objectives designed to assist the NTSB in meeting future requirements for accident investigation. Virtually all of the recommendations are within the purview of the NTSB to implement without the need for legislation or new regulations.

Strengthen the Party Process

The NTSB must consider methods for augmenting the current party process model in order to provide access to independent analytical and engineering resources during the investigation of high-profile accidents. The NTSB should not, however, augment the party system by including family representatives, plaintiff experts, insurers, or other individuals or organizations that have no direct involvement in identifying the technical cause of an accident. The following actions will help the NTSB adopt a strategic view of alliance-building:

- Perform a nationwide assessment of federal laboratories, universities, and independent corporate resources to identify the tools, facilities, and experts capable of augmenting NTSB resources. Seek formal memoranda of understanding and other forms of strategic alliances with these entities as required. The exercise of alliances to strengthen NTSB technical capabilities should be viewed as a mechanism for augmenting the existing party system, not corrupting it.
- Issue a Board order establishing formal guidelines allowing the chairman discretionary authority to form independent review and assessment teams. These guidelines should define a process by which the chairman, with the support of Board members and in consultation with the OAS, can move aggressively to supplement NTSB teams with outside expertise. The Board order should make it clear that the approval of participating parties is not required for the NTSB to assemble investigative teams with alliance representatives or to include alliance experts as part of ongoing party analyses, should this be deemed beneficial to the technical work.

The current party pledge reflects an unrealistic view of the factors at work during an investigation. This pledge should be revised to reflect the actual and inevitable involvement of parties in related civil litigation and the widespread use of NTSB materials in the litigation process. In particular, the NTSB should assess available sanctions to enforce party rules and should apply such sanctions consistently and expeditiously when the rules of party participation have been violated.

Additional information concerning an accident that comes to light following litigation could significantly affect aviation safety. The NTSB should provide a procedural mechanism other than formal reconsideration to allow review of important safety-related findings. The NTSB should interpret existing rules governing petitions for reconsideration to allow submissions from nonparties, including claimants or their attorneys, when new evidence relating to probable cause or safety recommendations has been discovered through civil litigation. Such an interpretation might, for example, allow supplemental material to be appended to the public record. The NTSB should not require formal proceedings for nonparty submissions unless the submissions make it necessary to amend the probable cause finding or issue additional safety recommendations.

Create a More Expansive Statement of Causation

The statement of causation is the Safety Board's most controversial output; it is crucial that this statement be as clear and complete as possible. The NTSB should view the probable cause statement not simply as the final investigative word on an accident but in a larger context, as a signpost supporting future aviation safety goals. To accomplish this, the NTSB should move away from simplistic, one-line probable cause statements and instead *consistently* adopt a comprehensive statement that reflects the reality that a modern aircraft accident is rarely the result of a single error or failure.

The probable cause statement should clearly state the principal event or failure that led to the accident. The probable cause statement should then also include all related causal factors. These causal factors should be ranked in terms of their contribution to the event, according to methods to be outlined in Safety Board investigative procedures.

Modernize Investigative Procedures

The NTSB should take a more proactive stance in examining incidents, both to support far-reaching national goals and also to ensure that its investigators are "up to speed" should a major accident occur. NTSB procedures for prioritizing workload should be modified to include

a modest expansion in the resources dedicated to identifying and investigating aircraft incidents that have critical safety implications. In parallel, the NTSB should perform more safety studies and report safety trends from incident analyses. Reflecting national priorities and concerns, the NTSB should also formally recognize a legitimate role in the investigation of breaches of security, both in the air and on the ground.

The NTSB should undertake a comprehensive independent review of its existing statutory mandate to investigate all general aviation accidents, potentially leading to the legislative revision of this requirement. The growth of general aviation traffic and the proliferation of various types of personal aircraft are likely to increase the NTSB's workload, both in terms of the number of accidents and the complexity of general aviation investigations.

The NTSB should examine whether every general aviation accident raises nationally important safety issues sufficient to merit the expenditure of NTSB resources in conducting an investigation. The NTSB should consider the feasibility of training state and local investigative authorities to conduct more routine general aviation accident investigations, thereby confining the NTSB role to data collection and dissemination, the investigation of complex accidents of national importance, and the conduct of broad-based safety studies in the general aviation field.

The NTSB must also adopt strategies that successfully meet the challenge of modern air accident investigation, while reflecting a broadening investigative role. Most important, the NTSB should comprehensively review procedures and contrast them with the increasingly complex world of aviation. Modernizing the methods used to investigate accidents should begin with these steps:

- Review the role and responsibilities of the IIC, especially for major aircraft accident investigations. The NTSB should explore the notion of recasting the IIC role into one of a PM in charge of the accident investigation and should provide the tools required to manage the ensuing effort.

- Examine alternative team structures (such as the notional meta-team concept), particularly for the investigation of complex-system accidents. Compare and contrast the approaches of other failure boards, such as those used by the U.S. Air Force and NASA. This examination should stress the efficacy of multidisciplinary teams to examine complex events.
- Evaluate the potential of a senior advisory team concept that may better utilize the NTSB's senior investigative staff. The use of senior staff members to manage investigations should be limited. Instead, the NTSB's most senior staff members should be viewed as a shared resource, a source of expert team review, and as mentors to junior investigators to promote the development of midlevel managers.

Streamline Internal Operating Procedures

Several actions can reduce workload and improve the flow of investigative products. In particular, the current process for producing the Final Accident Report should be less cumbersome and more visible to those who must ultimately approve the product--the Board members. The following recommendations should reduce the time and resources required to complete accident investigations:

- Provide the NTSB chairman and Board members with the option of requesting a technical peer review of final accident reports and safety studies prior to review by Board members. This course should be reserved for complex investigations and should have the aim of ensuring the technical excellence of the final product. As a baseline, the peer-review team should consist of at least three technical experts selected at random from NTSB senior investigators. One of the three experts should be a reviewer external to the NTSB with no party affiliation. Peer review comments should be confidential, and the accident investigation team should formally respond to peer-review comments.
- Enforce strict time lines for the preparation and release of Final Accident Reports. The NTSB should lengthen its one-year

baseline for major accidents to a more realistic 18-month baseline, with a 30-month maximum for any investigation. The current Board order describing the overall process for report preparation should be revised to include this time line and to allocate a greater percentage of the time to investigation and analysis than to report writing.

One final set of streamlining recommendations relates to the way in which the NTSB manages information. Safety Board investigations involve fact-finding and analysis, and the final product is information. The quality of NTSB products must be very high, and accuracy must be ensured. This assurance depends, to a large extent, on the agency's ability to acquire, control, and distribute large quantities of information. The following recommendations are designed to improve the NTSB's internal and external information flows:

- Elevate information management to a higher level in the organization by establishing an Office of Information Management. This office would be responsible for the overall management of information and would integrate public inquiries, information technology, and analysis and data functions in the current NTSB structure. The office would integrate Safety Board functions such as notation schedules and the management of dockets and also be responsible for logging all information relevant to investigations that moves *into* or *out of* the NTSB.
- Improve the quality and management of accident or incident information by assigning one full-time person the task of quality control. This individual would ensure the coordination of accident record, recommendation, and publication databases; maintain a tight linkage between the information-management and project-management functions; and validate the ongoing technical accuracy of NTSB-generated data systems that are being propagated outside of the Safety Board.
- Evaluate the potential value of a "knowledge agent" to improve electronic access to worldwide incident databases, monitor and establish relationships with outside sources of expertise, and

ensure dissemination of NTSB-generated knowledge to the broader aviation community.

Better Manage Resources

Reducing the NTSB staff's workload is a prerequisite to improved training and more effective and timely completion of investigations. A key to success in this area is the development of management practices and tools that allow tracking the expenditure of resources. The NTSB must establish the requirements for management systems that achieve this goal. Without such practices, there is little assurance that additional resources provided to the Safety Board will be effectively employed. The NTSB should take the following steps:

- Implement a system that permits full-cost accounting of all Safety Board activities. This could be accomplished by modifying the NTSB's current relationship with the DOT for time and attendance reporting, or, preferably, by establishing an independent NTSB timekeeping function. Individual project numbers should be assigned to each investigation. Specific project numbers should also be assigned to support activities, such as training, with a level of exactness that would ensure a comprehensive view of NTSB operations. Time charges and other expenditures for a given project should be merged and provided to project managers at least biweekly. The NTSB should endeavor to complete the implementation of an integrated cost accounting system within one year.
- Enact project management practices at all levels by assigning schedules and budgets to all investigations and safety studies. Project workload should be actively balanced across technical efforts at the level of the Office of Managing Director. Detailed project schedules should also be prepared electronically and made available throughout the NTSB internal computer network in near real time.

Maintain a Strategic View of Staffing

The NTSB should continuously assess its long-range staffing requirements, taking into account the magnitude and nature of accident

investigation demands, skill needs implied by the emerging fleet mix, and fluctuations in the labor market. Such a staffing plan should be made a Safety Board priority. Several actions are needed:

- Seek an initial increase in the number of OAS technical staff of 12 to 14 percent over fiscal year 1999 levels to reduce excessive workloads, permit more time for training, and support the expansion of incident investigations.¹
- Explore the feasibility of sharing work loads through personnel exchange arrangements with other civil, military, and private centers with accident investigation expertise. Intergovernmental Personnel Act assignments are one such exchange approach.
- Assess the effects of aging staff on the NTSB's future skill mix, especially in terms of replenishment of critical expertise. The NTSB should include in its staffing plan methods for using mentoring, training, and hiring to ensure the maintenance of critical skills.
- Assess the competitiveness of the NTSB's compensation structure by comparing it with that of government and industry. Consider broader use of compensation options within the existing pay system, including signing and retention bonuses, national resource specialist positions, senior-level and senior-technical positions, and senior executive service positions.

Streamline Training Practices

The NTSB must assign a higher priority to training a staff capable of unquestioned leadership during an investigation. In streamlining existing training programs, the NTSB's senior staff must create a balanced training program that builds management skills, professional capabilities, and investigative expertise. The following recommendations attempt to broaden the NTSB's approach to training:

¹Such an increase is designed to reduce the average OAS workweek to the threshold of an extended workweek, while including allowances for increased training and incident investigation, and a credit for the introduction of process efficiencies. The adequacy of such a personnel increase should be monitored and adjusted as appropriate.

- Create a baseline training plan that establishes standards for each major job title. This plan should first set minimum baseline training requirements for various levels within the NTSB. Technical managers at the NTSB should then build upon this baseline by selecting elective training options tailored to the needs of each employee. Training accomplishments should be maintained in employee records. Costs for training accomplished within the baseline plan should be managed within the NTSB's overhead structure. Elective training, however, should be paid from training accounts assigned to individual technical managers. An emphasis on training should be engendered by making staff training accomplishments part of each manager's work performance evaluation. A minimum of two weeks per year of formal elective training should be established, with a three-week minimum goal for less-experienced staff.
- The NTSB should create a full-time training officer position to build and maintain the training plan. The training officer should be responsible for identifying and developing training opportunities and maintaining an agency-wide database of training opportunities from which technical managers can identify elective training to meet the needs of individual staff members. Although emphasis should be placed on creating coursework that exploits both on-site technical capabilities and the senior staff for training and teaching, the training officer should also maintain a complete catalog of relevant outside training opportunities. Training opportunities should be listed on an electronic catalog available as an internal Web page. The training officer should also prepare training budgets and regularly inform the NTSB chairman on the status of the training program.
- The NTSB general counsel should clarify the NTSB's policy regarding gratuities in relation to the acceptance of training opportunities offered by private corporations and other government agencies. The acceptance or denial of training

opportunities should not rely on ad hoc interpretations set forth by the Office of the General Counsel. Rather, they should be evaluated on their technical merit and cost by following NTSB guidelines and elucidated in a standing board order. The NTSB staff should be encouraged to seek outside sources of training when that training is responsive to emerging aviation trends and complements internal training programs.

- Emphasize cross-training whenever possible to build multidisciplinary capabilities. The NTSB should consider staff rotation through NTSB organizations, the use of in-house colloquia to share skills and resources, and the expanded use of invited speakers and site visits to gain insights into alternative methods. The NTSB should emphasize broadly based training, and limit training with very focused outcomes. For example, training resulting in the type rating of pilot-investigators should be limited to exceptional circumstances.

Improve Facilities for Engineering and Training

The NTSB should review its internal technical capabilities to support future accident investigations, including the potential for crash reconstruction and the requirements for system testing in support of complex accident investigations. The Safety Board's long-term requirements for facilities should recognize that facilities can serve a dual function and so include consideration of using them for staff training. To conduct this review, the NTSB should commission an external study that looks at technical and training requirements for the next 15 to 20 years for all transportation modes. This multimodal study should

- evaluate projected analytical facility and laboratory requirements based on assessments of future accident trends, including the ability of the NTSB to investigate complex failure events
- analyze the cost and efficacy of building and equipping new facilities to meet projected needs, as opposed to procuring services and/or obtaining additional capabilities through

strategic alliances with other government agencies, the private sector, and academia

- include the cost and efficacy of using NTSB technical laboratories and capabilities for training instead of obtaining training from outside sources
- specifically highlight the cost and efficacy of an NTSB flight-simulator facility to support investigations and training.

The NTSB should also improve its technical ability in the areas of modeling and simulation. The number and fidelity of simulation tools should be expanded, and aircraft models should be available in-house for all transport-category aircraft currently operating in the fleet.

The NTSB has become a critical link in the chain that ensures the safety of the traveling public in the United States and throughout the world. That link cannot be allowed to weaken. However, unless purposeful steps are taken to modernize the internal workings of the NTSB, supplement its overloaded workforce, and enhance the resources and facilities available to the investigative staff, the continued vitality of the NTSB cannot be guaranteed. It is in the interest of everyone who travels, by whatever mode, to ensure that the NTSB continues to set the world standard for independent accident investigation.

APPENDIX A HISTORY AND STRUCTURE OF THE NTSB

This appendix provides a brief history of the NTSB and an explanation of the organization's structure. It also discusses the NTSB's recently acquired family assistance responsibility to respond to issues involving victims' family members in the wake of transportation accidents.

NTSB HISTORY AND STATUTORY AUTHORITY

During the early years of U.S. aviation, the government did not play a formal role in promoting the safety of civil aircraft (National Research Council, 1998, p. 10). The Air Commerce Act of 1926 was the first federal law in the United States to govern civil aviation.¹ The 1926 act granted broad authority to the secretary of air commerce, under the Department of Commerce, to ensure a high level of safety and to "investigate, record and make public the cause of accidents in civil air navigation."

The Aeronautics Branch issued the first civil aviation safety regulations, including the first standards for licensing of or the certification of aircraft (National Research Council, 1998, p. 10). As transport aircraft became more sophisticated, transcontinental air travel became more commonplace. By the late 1930s, the number of air carrier accidents and the number of fatalities began to capture the public's attention. Interest was particularly heightened by the death of Knute Rockne in 1931, the deaths of Will Rogers and Wiley Post in 1935, and by the crash of the *Hindenberg* in 1937.

Modifications to the Air Commerce Act were made in 1934 and 1937 to strengthen the accident investigation process. The secretary of commerce was specifically authorized to hold public hearings to inquire into the facts and circumstances surrounding aircraft accidents and to make public statements regarding the cause of the accidents. In 1937, the

¹Pub L. No. 69-254, 44 Stat. 568 (1926).

secretary adopted administrative regulations establishing aviation accident investigation procedures (Miller, 1981).²

The modern NTSB effectively rose from the wreckage of a 1935 accident that took the life of Senator Bronson M. Cutting of New Mexico. Cutting died in the crash of a TWA DC-2 traveling from Albuquerque to Kansas. Losing one of their own colleagues prompted members of Congress to consider the use of capable investigative personnel who were protected from political influence. The solution was the Civil Aeronautics Act of 1938, which established three agencies to regulate air safety and economics: (1) the Civil Aeronautics Authority to legislate safety and promote economic development of the civil aviation industry; (2) the Administrator of Aviation to implement safety regulations; and (3) the Air Safety Board to investigate accidents. In 1940, the Civil Aeronautics Act was amended to eliminate duplication in the duties of the three agencies.

The 1940 amendment established the Civil Aeronautics Administration (CAA), to be responsible for all safety regulations, and the Civil Aeronautics Board (CAB) to be responsible for all economic regulations and accident investigations. Although technically under the control of the Department of Commerce, the CAB was to conduct its investigations independent of the influence or control of the secretary of commerce.

The Federal Aviation Act of 1958 was the result of a growing number of civil aviation accidents, including a grisly accident over the Grand Canyon involving the midair collision of a TWA Constellation and a United Airlines DC-7. At the same time, GA was experiencing 3,500 to 4,000 accidents per year. The introduction of jet aircraft signaled a major challenge to the civil aviation community which was having difficulty coping with safety matters.

The Federal Aviation Act established the FAA as a separate agency reporting directly to Congress and the president.³ The FAA's functions were similar to those of the CAA, including the generation and enforcement of the FARs governing every aspect of civil aviation from

²In this 1981 article, Miller provides a detailed statutory history of aviation accident investigation authority.

³Pub. L. No. 85-726, 72 Stat. 731 (1958).

the design and manufacture of an aircraft to its operation. The jurisdiction of the CAB was left essentially unchanged by the 1958 act (McCormick and Papadakis, 1996, pp. 149-151).

The 1958 act laid the statutory framework for the modern NTSB. The CAB was granted the authority to make rules and regulations governing notification and reporting of accidents, obtain assistance as necessary from other government agencies, including the FAA, and determine the facts, conditions, and circumstances and the probable cause of accidents. The CAB was also to make recommendations to the FAA administrator that would prevent similar accidents in the future and to conduct special safety studies pertaining to the prevention of accidents.

The CAB was charged with the responsibility of preserving and examining aircraft parts and property involved in an accident and, in the case of fatal accidents, of ordering autopsies. A provision of the 1958 act allowed the appointment of a special Board of Inquiry, including two members appointed by the president, to investigate accidents "involving substantial questions of public safety in air transportation." Finally, a provision of the act rendered CAB reports relating to an accident or investigation inadmissible as evidence in any suit or action for damages arising out of the accident.

In 1966, President Lyndon Johnson created a twelfth cabinet department, the DOT, and the FAA was made part of it. The responsibilities of the CAB were reduced to include only the economics of civil air transportation, including route structures, fares, and airline mergers. At the same time, a partially independent NTSB, composed of five presidential appointees, was created out of the structure of the CAB's Bureau of Safety and given responsibility for accident investigations for all modes of transportation. Initially, the NTSB fell under the oversight of the DOT, but after only a few years, concerns about undue influence and administrative interference from the Executive Branch on the supposedly independent NTSB finally led to passage of the ISBA in 1974.

The ISBA provides for a five-member Board appointed by the president, by and with the advice and consent of the Senate. No more

than three members may be appointed from the same political party and at least three members are to be appointed on the basis of technical qualification, professional, and demonstrated knowledge in accident reconstruction, safety engineering, human factors, transportation safety, or transportation regulation. The term of office for each member is five years, or the length of time remaining in a term when a vacancy occurs. Separately, the president designates a chairman of the board, also with the advice and consent of the Senate, and a vice chairman, each for a two-year term. The chairman serves as the chief executive and administrative officer of the board.⁴

The basic statutory authority for the Safety Board's operations derives from 49 USC §1131. The NTSB is responsible for the "investigation, determination of facts, conditions, and circumstances and the cause or probable cause" of all accidents involving (1) civil aircraft, (2) rail accidents that involve a passenger train or in which there is a fatality or substantial property damage, (3) pipeline accidents in which there is a fatality or substantial property damage, (4) highway accidents selected in cooperation with state authorities, and (5) marine accidents occurring on the navigable waters or territorial seas of the United States (in conjunction with the Coast Guard).

A Safety Board investigation has priority over any other by another department, agency, or instrumentality of the U.S. government.⁵ This

⁴49 USC §1111.

⁵NTSB regulations provide that nothing shall impair the authority of other federal agencies to conduct investigations of an accident or incident or to obtain information directly from the parties involved or from other witnesses (49 CFR §831.5). The NTSB's priority over investigations by other departments or agencies was a significant issue in the investigation of the July 1996 crash of TWA Flight 800. In that instance, the Federal Bureau of Investigation (FBI) asserted its primacy based upon initial suspicions that the crash was the result of criminal or terrorist activity. The working relationship between the NTSB and the FBI has been the subject of an ongoing review by the Subcommittee on Administrative Oversight and the Courts of the Senate Judiciary Committee. That Subcommittee, chaired by Senator Charles Grassley (R-IA), conducted a lengthy hearing on the actions of the FBI in the TWA Flight 800 investigation on May 10, 1999. The issue of accident scene priorities was also discussed in testimony concerning the reauthorization of the NTSB delivered by NTSB Chairman Jim Hall before

includes priority over criminal investigations as well as the discovery process attendant to civil litigation brought against any federal agency that may have been directly involved in an accident. The Safety Board is responsible for arranging appropriate participation by other departments, agencies, or instrumentalities in the investigation. However, those departments or agencies may not participate in the decision of the Safety Board about the probable cause of the accident.

The NTSB is authorized to make safety recommendations to federal, state, and local agencies and private organizations to reduce the likelihood of recurrence of transportation accidents.⁶ It may initiate and conduct safety studies and special investigations on matters relating to safety in transportation, assess techniques and methods of accident investigation, and evaluate the effectiveness of transportation safety consciousness and efficacy in preventing accidents of other government agencies. The Safety Board also evaluates the adequacy of safeguards and procedures concerning the transportation of hazardous materials.⁷

After the NTSB submits a recommendation about a transportation safety matter to the secretary of transportation, the secretary has 90 days in which to provide a formal written response to each recommendation. The response must indicate whether the DOT intends to adopt the recommendation, in whole or in part, or reject it. The response must either provide a timetable for completing the procedures called for in the recommendation or a detailed explanation of the reasons for the DOT's refusal to adopt it. The secretary of transportation must report to Congress every year on the DOT's actions regarding each proposed NTSB recommendation.

the Aviation Subcommittee of the House Committee on Transportation and Infrastructure on May 6, 1999. In that testimony, Chairman Hall indicated that interagency coordination between a safety investigation and a criminal investigation can be a complicated matter. He articulated the Board's belief that there is a significant need for a restatement of congressional intention in this area because of the increasing likelihood that other agencies will be on the scene and operating in competition with the work of the NTSB. (See also "Heed the Lessons of the Flight 800 Mess," May 17, 1999.)

⁶49 USC §1116.

⁷49 CFR §800.3(a).

The NTSB may conduct public hearings as part of the investigative process, with testimony administered under oath. The Safety Board also has the power to subpoena necessary witnesses and evidence. The NTSB may enforce such subpoenas by bringing a civil action in federal district court; the court may punish a failure to obey an order to comply with an NTSB subpoena as contempt of court.⁸

Civil actions may be brought in district court to enforce the provisions of the authorizing statute that allow the inspection and testing of aircraft and the conduct of autopsies. Civil penalties of no more than \$1,000 may be imposed for violation of those civil aviation investigation provisions. Any person who knowingly and without authority removes, conceals, or withholds a part of a civil aircraft involved in an accident or property on the aircraft at the time of the accident can be fined under the provisions of Title 18 of the U.S. Code, imprisoned for no more than 10 years, or both.⁹

The Safety Board is also granted additional powers to procure the services of experts or consultants without regard to most government contracting requirements; to procure the services, equipment, personnel, or facilities of other government agencies; to accept voluntary and uncompensated services; to accept gifts of money and other property; to appoint advisory committees composed of qualified private citizens and officials of the federal, state, and local government; and to contract with nonprofit entities to carry out studies related to the duties and powers of the Safety Board.¹⁰

In conducting aviation accident investigations, the NTSB is authorized to enter property where an accident has occurred or where the wreckage is located and to do "anything necessary" to conduct the investigation.¹¹ The ISBA contains provisions that authorize the Safety Board to compel the production of witnesses and evidence, examine and test physical evidence (including the aircraft and any component part), inspect records and facilities, and order autopsies. The Safety Board is

⁸49 USC §1113(a).

⁹49 USC §1155.

¹⁰49 USC §1113(b).

¹¹49 USC §1134(a)(1).

granted the exclusive authority and discretion to decide how testing will be conducted, including decisions about the type of test, who will conduct it, and who may witness the test.¹² Consistent with the needs of the investigation, examinations or tests are to be carried out to the maximum extent feasible, to preserve evidence related to the accident.

ORGANIZATION OF THE NTSB

The NTSB is a small government agency by any standard. As shown in Figure A.1, the Safety Board's organization is composed of the following principal components:

Office of the Managing Director. The managing director assists the chairman in the discharge of his functions as executive and administrative head of the Safety Board. The managing director coordinates and directs the activities of the staff, is responsible for the day-to-day operation of the Safety Board, and recommends and develops plans to achieve the Safety Board's program activities. Human resources and facilities also fall within the purview of the managing director's office.

Office of Government, Public, and Family Affairs. This office releases current, accurate information concerning the work, programs, and objectives of the NTSB to the public; Congress; other federal, state, and local government agencies; the transportation industry; and the news media. This includes the dissemination of information about the conduct and status of major commercial aviation accident investigations. The Office of Family Affairs, established following the enactment of the Aviation Disaster Family Assistance Act of 1996, is discussed later in this appendix.

Office of Safety Recommendations and Accomplishments. Since 1968, the NTSB has issued approximately 11,000 safety recommendations concerning all modes of transportation to more than 1,300 recipients in government, industry, and associations (National Transportation Safety

¹²49 USC §1134 (d). Challenges to the exercise of the Board's discretion as to how its investigations would be carried out resulted in an amendment to the Board's authorizing legislation in the Independent Safety Board Act Amendments of 1990, Pub. L. No. 101641, 104 Stat. 4654, amending 49 USC app.1903(b)(2).

Board, July 1998). The Office of Safety Recommendations and Accomplishments is responsible for implementing these recommendations and for maintaining a database designed to track all transactions and activities related to each NTSB recommendation. Within the NTSB, recommendations that result in the correction of problems that cause accidents are considered to be the Safety Board's most important work product. The agency contends that innumerable lives have been saved because of Safety Board recommendations.

The most frequent recipient of NTSB recommendations is the DOT, and its modal administrations, such as the FAA, the Federal Railroad

NTSB Headquarters Operations

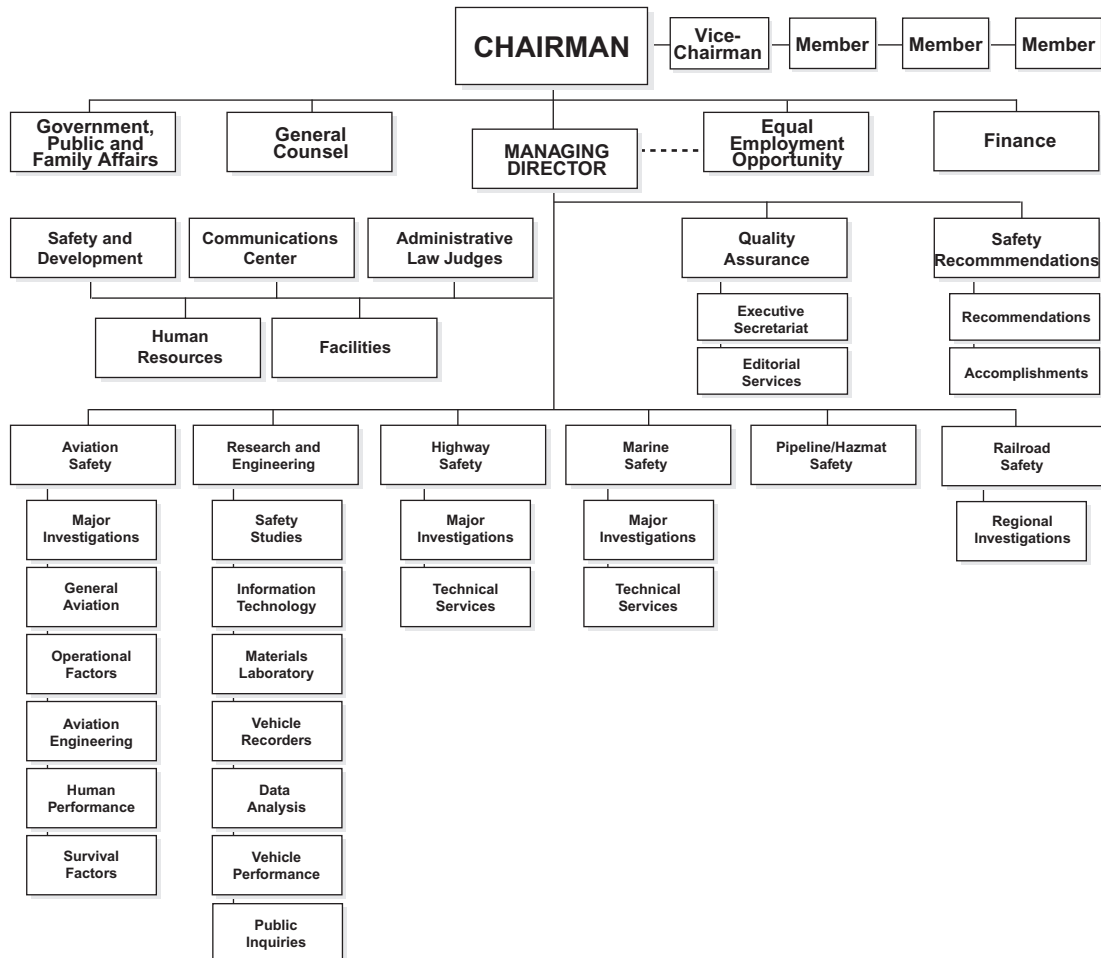


Figure A.1--NTSB Organizational Chart

Administration (FRA), or the Coast Guard. In the United States, each transportation industry operates in a different regulatory environment. In aviation, an industry that is heavily regulated by the FAA, most NTSB recommendations are directed to the FAA. The highest percentage of NTSB recommendations have addressed aviation safety: According to NTSB statistics, 83.87 percent of these recommendations are accepted.

Recommendations made by the NTSB are derived from three main sources:

- First, the most visible and sweeping are those recommendations that result from investigations of major aviation accidents. For example, the NTSB has issued 24 recommendations relating to the rudder system on the Boeing 737 stemming from the 1994 crash of USAir Flight 427 outside Pittsburgh and the 1991 crash of United Airlines Flight 585 in Colorado Springs. Recommendations are not delayed pending an investigation's completion and the Final Report's issuance--recommendations can be, and often are, issued at any time during an investigation when it becomes clear to investigators that a safety problem merits immediate attention.
- The second source of recommendations are those proposed by NTSB field investigators, who investigate more than 2,000 civil aviation accidents per year, most involving GA aircraft. In some instances, these recommendations have broad national application; in others, the recommendations focus on a mechanical problem with a particular aircraft or airport facility.
- The third source of safety recommendations are those derived from NTSB safety studies conducted in all transportation modes. These recommendations often have national implications because they are based on many accidents occurring over a long period of time.

In 1990, the NTSB adopted a formal program to highlight certain transportation safety issues that required the highest visibility and the strongest follow-up activity. The program is known as the "Most Wanted" Safety Recommendations Program.

A transportation safety issue is considered for placement on the "Most Wanted" list if it will enhance safety on a national transportation system level. Issues on the list have a high level of public visibility or interest, they are associated with previous loss of life or substantial property loss, and they pose a high risk for future losses. Only recommendations that can be implemented in a reasonable period of time are considered for the list.

The issues placed on the "Most Wanted" list are highly publicized with press conferences and media releases; media interviews with Safety Board members and senior staff; testimony at congressional, state, and local legislative hearings; speeches to trade and industry groups; submission of rulemaking comments; and NTSB participation in seminars and conferences. The Safety Board attempts to keep the number of items on the "Most Wanted" list small so as not to dilute the impact of the program. Only the Safety Board acting at an open meeting can place issues on the list, or remove them. NTSB staff members report semiannually on the progress of issues on the list and make recommendations to the Safety Board concerning the addition or removal of items.

Office of the General Counsel. The Office of the General Counsel provides legal advice and assistance to the Safety Board and its staff; prepares Safety Board rules, opinions, and orders; and represents the Safety Board in civil actions to which the Safety Board is a party or in which the Safety Board is interested. The Office of General Counsel advises and assists the Safety Board and its personnel in the fulfillment of the Safety Board's statutory responsibilities, representing the Safety Board in legal proceedings as necessary.

Principal among the matters in which the Office of General Counsel advises and assists the Safety Board is the investigation of civil aviation accidents in the United States and significant accidents in the other modes of transportation, and the study and issue of safety recommendations aimed at preventing future accidents. Additionally, the Office of General Counsel serves as legal advisor to the Safety Board in its capacity as the appellate authority for certain disciplinary actions

taken with regard to the certificates of airmen, mechanics, and mariners.

Office of Aviation Safety. The responsibilities of the OAS are discussed throughout this report. The OAS investigates all major commercial aviation accidents, and is the focus of much of the research conducted for this study. OAS investigators and specialists investigate the factual circumstances of every major crash (both on site and afterward at NTSB headquarters), prepare the final reports for submission to the Safety Board (including a recommendation as to the probable cause[s] of an accident), initiate safety recommendations to prevent future accidents, and participate in the investigation of accidents that occur in foreign countries that involve U.S. registered or U.S. manufactured aircraft.

In addition, the OAS encompasses the regional offices and field offices that are responsible for investigating GA accidents. The NTSB maintains six regional offices located in Miami; Chicago; Arlington, Texas; Seattle; Los Angeles; and Newark, New Jersey. Four of the regions have smaller field offices. Regional and field office personnel constitute about half the total OAS staff. Because the NTSB is required by statute to investigate every civil aviation accident, more than 2,000 GA accident investigations are conducted each year.

Office of Research and Engineering. The ORE is composed of six divisions: Safety Studies, Information Technology, Materials Laboratory, Vehicle Recorders, Analysis and Data, and Vehicle Performance. This office provides technical support to all NTSB investigative offices, including the OAS.

The safety studies program is a very important part of the Safety Board's functions. A safety study is a research project on a transportation safety issue of national significance. In selecting subjects for safety studies, the Safety Board considers a subject's potential for reducing accident losses and for improving the effectiveness of other government transportation safety programs. Data to support a safety study may be collected from a review of existing NTSB accident reports, generated from a new set of investigations conducted specifically to support the study, or assembled from a

literature review on a particular subject. Once a safety study is completed, its findings and recommendations are presented to the Safety Board at a public meeting.

Another part of the NTSB's mandate is to maintain the official U.S. census of aviation accidents. For this purpose, the ORE maintains the NTSB's aviation accident database, which includes records of all accidents from 1962 to present.

ORE operates a materials laboratory in the NTSB headquarters building in Washington, D.C. The laboratory is staffed by engineers and physical science technicians who perform failure analysis studies on a wide variety of materials and components involved in both aviation and surface transportation accidents. Materials laboratory personnel also support general and major aviation accident investigations in the field as on-site consultants or group chairs, and they have on many occasions assisted foreign governments with accident investigations. Most materials analyses are completed within 60 days but their duration depends on the resources and priorities available at the time of the request. In complex investigations, these analyses may take considerably longer than 60 days.

Another critical investigative responsibility assigned to ORE is the handling of the CVR and FDR recovered from downed aircraft. These two data sources generate intense public interest after an accident. Normally, Safety Board staff are directly involved in recovering the recorders for accidents that occur in the United States. Analysis of the CVR extends well beyond transcription of the cockpit conversations. The NTSB's Engineering Services Laboratory is equipped to perform spectral analyses that support a comprehensive evaluation of all of the data obtained from the CVR. Provisions of the ISBA and NTSB regulations strictly control the discovery and use of CVR data and other similar material in civil litigation.¹³ The Vehicle Performance Division performs similar detailed analyses on FDRs, usually in conjunction with members of the FDR investigative group assigned to a major aviation accident.

¹³49 USC §1154 and 49 CFR §821.1 et seq.

Surface Transportation Modes. The NTSB's mandate extends to the investigation of significant accidents in other modes of transportation including rail, highway, marine, and pipeline. These investigations, including the determination of probable cause and the development of related safety recommendations, are conducted through the individual Offices of Railroad Safety, Highway Safety, Marine Safety, and Pipeline and Hazardous Materials Safety. Investigative procedures and processes for these modes are similar to those for aviation. Approximately 50 percent of the NTSB's budget and about half of the agency's personnel are committed to these modal offices.

FAMILY ASSISTANCE AND THE OFFICE OF FAMILY AFFAIRS

The Aviation Disaster Family Assistance Act of 1996 mandated that federal agencies engaged in disaster response coordinate their resources to better meet the needs of aviation disaster victims and their families. The NTSB was designated by the U.S. president as the lead federal agency for coordinating federal government assets at the scene of a transportation accident and the liaison between airlines and families.

Beginning in fiscal year 1997, the Safety Board was singled out to coordinate all federal assistance (including the Federal Emergency Management Agency, and the Departments of Transportation, State, Health and Human Services, Justice, and Defense) to the survivors and families of victims of catastrophic transportation accidents. Each accident presents a unique set of circumstances and requirements for meeting the needs of families. The Safety Board has developed a Federal Family Assistance Plan for Aviation Disasters to use in responding to such accidents. In addition, Congress directed domestic airlines to submit plans for providing family/survivor assistance to the Safety Board. In 1997, Congress passed the Foreign Air Carrier Family Support Act, requiring foreign air carriers to develop and file family assistance plans and fulfill the same family support requirements as domestic airlines. These plans are subject to review by the NTSB.

In creating an Office of Family Affairs, the Safety Board has sought to maintain a distinct separation between the family/survivor

assistance program and the Safety Board's technical accident investigative staff. This approach is consistent with the legislated prohibition against the participation of family members or claimants in the investigative process (Hall, September 28, 1998; May 6, 1999). To date, the Safety Board's Family Affairs staff has accomplished the following:

- Responded to the ComAir accident in Monroe County, Michigan; the Korean Air Lines accident in Guam; the Swissair accident in Halifax, Canada, and most recently, the American Airlines accident in Little Rock, Arkansas.
- Signed memoranda of understanding with several federal agencies.
- Provided families/survivors with information and updates on the status of the Safety Board's investigations.
- Established a 24-hour Communications Center to provide timely information to families and survivors.

The NTSB is responsible for coordinating the integration of federal and other resources to support the efforts of local and state governments and airlines so that they can meet the needs of aviation disaster victims and their families. The NTSB also helps make federal resources available to local authorities and the airlines. The NTSB also helps state and local authorities and airlines deal with major aviation disasters by providing for family counseling, victim identification and forensic services, communication with foreign governments, and translation services.

Increased governmental support for the families of victims of aviation disasters is no longer just a U.S. initiative. In September 1998, representatives of more than 160 nations attending the ICAO assembly adopted a resolution that will lead to guidance and standards for all nations to address the needs of aviation disaster victims and their families.

APPENDIX B

DATA ANOMALIES AND BASELINE ACCIDENT DATA

To gain a perspective on the NTSB's historical workload levels and output, RAND first needed a detailed baseline of accident rates. Although the NTSB keeps detailed records, the methods the agency uses to maintain and query information have changed over the years. Currently, several data systems, maintained by various offices within the NTSB, contain information about accidents.

Accident records are maintained primarily for archival purposes at the NTSB. Because the data records are rarely used for research, there was no contiguous historical data system that RAND could query to establish trends about the character of accidents over time. Therefore, to build the required database, RAND integrated the many NTSB accident data sets listed earlier in Table 6.3. Cross-checking was also performed against accident data records maintained by the FAA.

The task of integrating these records was a difficult one. Over time, the definition and quantity of information that is gathered following an accident has changed, as have the definitions of key parameters. Because the older records are kept primarily as archived data sets, they have been subject to little quality checking and validation. In addition, the older data sets did not share a common format with the newer data sets.

Some individuals at NTSB who provided assistance with RAND's analysis reported that when a large data entry backlog develops, temporary workers are hired to enter the data into databases quickly with neither oversight nor any assurance of accuracy. Single-point errors and systematic problems are not uncovered until a later analysis is performed. Some analysis has been performed on a limited basis by NTSB staff, and when errors were found the database was corrected. However, quality checks were not extensive and usually involved a small set of records for which paper reports were available for validation.

The AADB is a collection of disparate data sets that have been built at various stages during the evolution of the NTSB's computer and

database management systems. But discontinuity is only one of the problems affecting the quality and effectiveness of the NTSB's accident records. The various problems can be grouped into three distinct areas:

- **Inconsistent data entry practices.** The data record begins when an investigator completes an accident data entry form.¹ These forms often are incomplete when received by data entry personnel, and attempts to follow up for more information seldom yield complete and consistent records. The investigation staff is inconsistent in how they fill out accident data entry forms. Some investigators are meticulous in completing an accurate record, other less so. Interpretation of parameters, such as "severity of damage," is also inconsistent. These parameters are somewhat subjective. Incomplete records pose serious problems when NTSB data resources are later used to perform safety studies. A recent FAA study that attempted to correlate crash statistics with aircraft age and operational factors noted that incomplete data records, and a lack of data fields to enable users to acquire needed information, precluded the development of the required causal relationships (Federal Aviation Administration, July 1998).
- **Missing data.** Several gaps exist in the historical data record. For example, many final report dates are missing during the years 1983 through 1987, and approximately half of the records do not report aircraft airframe hours.
- **Data anomalies.** The NTSB's data records contain some obvious errors and inconsistencies. For example, a computer problem reported during the 1991 to 1992 timeframe was resolved with estimates that leave parameters such as the Final Report issuance date suspect. In general, little correlation exists among the various NTSB databases. When the AADB was compared with other databases, such as the publications record and the

¹NTSB Form 6120.1/2 dated November 1987 is used by pilot/operators to report accidents to the Safety Board. Field investigators dispatched to an accident investigation use an expanded form to acquire data for later entry into the NTSB's electronic database.

Safety Recommendations Information System (SRIS), many discrepancies were discovered.

Some of the analysis RAND had planned to conduct could not be performed because of the limitations of the integrated data record. RAND found numerous anomalies in the integrated record. Spot checks revealed that many errors were simple clerical mistakes. In other cases, the various ways in which information was input by investigators led to inconsistencies in the database.

Another subtle inconsistency in the data relates to the use of the term "report date," which has no precise meaning in the context of the database. "Report date" sometimes means the date when the Board approved the Final Accident Report and, at other times, the date when the document was printed. Sometimes, the only date recorded is the date when the report's findings were entered into the record. These dates are all roughly equivalent, provided each one of these processes occurs within a few days of each other, but as was seen in the 1990 to 1992 period, this may not be the case.

In general, RAND's analysis of the NTSB's record-keeping indicates a need for greater attention to quality control. Individual investigators need to be more systematic in how they input information so that the data are more consistent. If properly maintained, the NTSB's accident data record can be an important information resource for analytical monitoring of trends.

Appendix C
NTSB "PARTY PLEDGE"

STATEMENT OF PARTY REPRESENTATIVES TO NTSB INVESTIGATION

Aircraft Identification:

Registration Number _____

Make and Model _____

Location _____

Date _____

The undersigned hereby acknowledge that they are participating in the above-referenced aircraft accident field investigation (including any component tests and teardowns or simulator testing) on behalf of the party indicated adjacent to their name, for the purpose of providing technical assistance to the National Transportation Safety Board.

The undersigned further acknowledge that they have read the attached copy of 49 CFR Part 831 and have familiarized themselves with 49 CFR 0831.11, which governs participation in NTSB investigations and agree to abide by the provisions of this regulation.

It is understood that a party representative to an investigation may not be a person who also represents claimants or insurers. The placement of a signature hereon constitutes a representation that participation in this investigation is not on behalf of either claimants or insurers and that, while any information obtained may ultimately be used in litigation, participation is not for the purposes of preparing for litigation.

By placing their signatures hereon all participants agree that they will neither assert nor permit to be asserted on their behalf, any privilege in litigation, with respect to information or documents obtained during the course of and as a result of participation in the NTSB investigation as described above. It is understood, however, that this form is not intended to prevent the undersigned from participating in litigation arising out of the accident referred to above or to require disclosure of the undersigned's communications with counsel.

SIGNATURE

NAME (Printed)

PARTY

DATE

_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

APPENDIX D

RESULTS FROM RAND SKILLS AND EXPERIENCE QUESTIONNAIRE

NTSB data systems did not contain all the information necessary for RAND to perform its assessment of staffing, workload, and training issues, nor was sufficient time available for individual discussions with all technical staff members at NTSB. To broaden the coverage of its assessment, RAND developed a confidential structured questionnaire that it distributed in August 1998 to managers and technical staff at NTSB headquarters and at all regional and field offices across the United States. The questionnaire solicited information about the staff in the areas of

- position and background
- professional development
- accident investigation skills
- transportation mode-specific skills.

This information supplemented interviews with NTSB employees and analysis of products from NTSB data systems. The cover letter accompanying the questionnaire and the questionnaire itself can be found in Appendix E.

SAMPLE

The questionnaire was sent to every employee at the NTSB involved in accident investigation activities. The 269 recipients of the questionnaire represented the full population of relevant employees (see Table D.1). Researchers used the NTSB phone directory, which groups employees by organizational affiliation, to help identify appropriate questionnaire recipients. Although the NTSB's organizational structure left little room for ambiguity, RAND researchers also consulted with NTSB management and staff to ensure that all staff members in appropriate organizations were surveyed.

ADMINISTRATION

Questionnaires were mailed directly to each individual with a cover letter explaining the purpose of the survey (see Appendix E).

Respondents were not asked for their names, and mailing materials were included so that NTSB employees could return the surveys directly to RAND with no involvement of NTSB management. Survey recipients were assured that NTSB management would see only aggregated results from the survey, a principle to which researchers adhered throughout the study.

RAND researchers used several means to encourage responses. Concurrent with administration of the survey, RAND was conducting extensive interviews with various NTSB staff. At each of these meetings, the staff was reminded of the importance of returning their surveys. RAND researchers met frequently with NTSB management and gave them updates about the response rate, and encouraged them to remind employees to return questionnaires. NTSB management did in fact remind employees at regular NTSB meetings to return the surveys. Milestone briefings by RAND in August and December of 1998 provided quantitative results about response rates, underscoring the importance of encouraging employee responses.

Responses were entered into an Excel spreadsheet to facilitate analysis. Researchers analyzing the survey results performed the quality control function.

RESPONSE RATES

A total of 149 employees responded to the survey during the fall of 1998, representing a 55 percent response rate from a targeted population of 269 employees receiving the survey (see Table D.1). The greatest number of responses came from the OAS (at headquarters and regional offices) and the ORE. These offices, the largest in the NTSB, were the focal point for RAND's assessment because they perform aircraft accident investigations.

Because of the small samples, no comparisons were made for individual surface transportation offices, although some comparisons were made for the surface transportation staff as a group. In addition, results from the "Skills and Experience Inventory" portion of the survey were not used. The original intent was to survey, in a structured way, the skills of the NTSB staff by specialty area, but with a response rate of just over 50 percent and a median staffing depth of two in the OAS

Table D.1
Response Rates for RAND Skills and
Experience Survey

Category	Sent	Received	Percent Response
Aviation safety (HQ)	56	29	52
Aviation safety (Reg)	56	29	52
Surface transportation			
Highway	17	13	76
Railroad	14	12	86
Pipeline	15	10	67
Marine	11	4	36
Research & engineering	61	31	51
Safety recommendations	10	6	60
Government affairs	2	1	50
Managing director	1	1	100
Other regional offices	26	13	50
Total	269	149	55

specialties and one in the ORE specialties, RAND had no assurance of fully capturing a complete picture of the skills at the NTSB. There was no way to ascertain whether observed skill gaps were real or just reflected a failure of the relevant experts to respond.

APPLICABILITY OF THE RESPONSES

Because 55 percent of those receiving the survey chose to respond, the respondents corresponded to a self-selected subgroup of the technical staff at the NTSB. For the most part, RAND had no independent means to verify whether the respondents were a representative subgroup. If this were possible using alternative data sources, the survey may not have been required in the first place. RAND did acquire information late in the study that permitted comparisons of survey responses and actual experience at the NTSB.

Mean experience levels computed using internal NTSB data sources fell well within the 95 percent confidence interval for the mean experience level derived from survey responses. Similarly, training levels reported by OAS employees in the questionnaire generally fell within the range of training hours recorded by the administrative officer in the OAS.

DESCRIPTION OF THE SURVEY

RAND research used questionnaire responses regarding position, background, and professional development of the NTSB staff in the following areas:

- Position and Background
 - NTSB office symbol
 - Management or staff
 - Nature of prior employment
 - Educational background
 - Total transportation experience
 - NTSB experience
 - Age
- Professional Development
 - Time for training
 - Duty cycle
 - Average workweek
 - Sources of professional development

Position and background questions provided a means to characterize the workforce. This information was also correlated with answers to professional development questions to characterize how different populations worked and trained. Respondents identified the office within which they worked at the NTSB. This was used to compare the characteristics of different populations of data. They also provided information about prior employment, years of experience, educational attainment, and their age.

Professional development questions addressed the aggregate amount of time employees worked, how they spent their time, and where they obtained training. Respondents were asked a simple question regarding whether they had adequate time for training. The duty cycle question provided a structured set of choices for respondents to provide a breakdown of how they spent their time "during the past year." This provided a rich level of detail unavailable in normal NTSB data systems.

Similarly, the questionnaire asked respondents the number of hours they worked, on average, during a representative week during the past year. They were expressly asked to include time worked in excess of 40

hours, as appropriate. The question was asked in this manner to encourage respondents to average their varying workloads at the NTSB over a year's period to arrive at an answer. There is also some evidence that using a "last year" reference period rather than a "last week" period may reduce the tendency for exaggeration (see the next section). Finally, the questionnaire provided respondents with a structured set of choices to identify their sources of professional development.

ACCURACY OF SELF-REPORTED WORKWEEKS

The accuracy of self-reported workweeks is a subject of considerable research, as investigators try to measure trends in working hours and more generally how Americans spend their work time (Robinson and Bostrom, August 1994, pp. 11-23; Robinson and Godbey, 1997; Schor, September 26-28, 1997; Jacobs, December 1998, pp. 42-53). In a paper and subsequent book, Robinson strongly endorses the time-diary approach as the best means for collecting accurate information about work activities. This data-intensive approach involves distributing thousands of time diaries to respondents who enter information in 15-minute increments for one day.

By requiring various groups of respondents to account for their time on different days of the week, researchers can then construct synthetic workweek estimates by adding equal proportions of each day of the week, while relying on the large sample to compensate for any atypical days reported by certain respondents (Robinson and Godbey, 1997).

Robinson compared self-estimates of workweeks with time-diary results, using the latter as an objective standard, and found respondents tended to overestimate their workweeks as estimated workweeks grew longer, particularly for those claiming workweeks of over 45 hours.¹ Robinson concedes that the diary data employed in the analysis "were not designed nor intended to uncover the discrepancies . . . described" and call for methodological experiments

¹In the 40- to 44-hour estimated workweek category, estimates exceeded the time diary results by about 2 hours. This grew to 3 hours in the 45- to 49-hour estimated workweek category, and 9 hours in the 50- to 54-hour category (Robinson and Bostrom, August 1994, pp. 16-17).

to draw distinctions between measurement techniques (Robinson and Bostrom, August 1994, pp. 19-20). Finally, he suggests, "While they may exaggerate their work hours, there is no question that people who estimate that they work long hours actually do put in more hours on the job" (Robinson and Godbey, 1997, p. 193).

A recent paper offers a new interpretation of Robinson and Ann Bostrom's results. Jacobs developed a new measure of the workweek, derived from departure and return times. He then compares the resulting workweeks with self-reports, tests for factors that might introduce bias in self-reports, and considers how the differences in reference periods for estimates could influence the results (Jacobs, December 1998, pp. 42-53). His results indicate that some of the observed discrepancies in time-diary and self-reported workweeks are the consequence of a statistical artifact.²

The new measures of workweek largely corroborate self-reported measures. Jacobs tested social psychological factors, nature of job factors, and demographic factors to determine whether they helped explain discrepancies between calculated and reported workweeks. He found few predictor variables, indicating that errors in self-reported measures appear to be largely random in nature. Jacobs also found that changing reference periods of workweek estimates from "last week" to "last year" may reduce the tendency for respondents to exaggerate the number of hours worked.

These academic discourses on the efficacy of various means for measuring workweeks and the results derived from them have clearly not evolved to a consensus. The RAND survey selected a reference period for the workweek question that was not specifically tied to the day the survey was administered or specific to the prior week. This approach may help to reduce dispersion in workweek estimates and may also be better suited to measuring workweeks in an organization such as the NTSB, in which unpredictable random accident occurrences can affect workloads.

²Jacobs demonstrates that discrepancies that appear as exaggerations "may instead be merely a reflection of the statistical artifact of regression to the mean between two measures that are correlated with some error" (Jacobs, December 1998, p. 46).

RAND wanted respondents to average out the workweeks they had experienced. The self-reported workweek estimates complemented other indicators of workload, such as overtime payments, that were available in the NTSB's data systems.

STATISTICAL COMPARISONS OF SUBSETS OF RESPONDENTS

The RAND analysis statistically tested for differences in workweeks, training activity, experience levels, and other factors, across various subsets of respondents. For example, RAND analysis compared whether employees from the OAS tended to have longer workweeks than other employees at the NTSB by using the Student's t-test. The t-test assumed a two-tailed distribution and that the two samples had unequal variance. This comparison was used to determine the probability that the two samples arose from two underlying populations having different mean measures.

STAFFING AND WORKWEEK RESULTS

Total Professional Experience of OAS Members and Other Respondents

Respondents from the OAS tended to have more total years of experience as transportation professionals than did other respondents (see Table D.2). This includes applicable experience prior to joining the NTSB. Differences between the experience level of OAS respondents and other respondents were significant at the 98 percent level using a t-test.

Ages of NTSB Technical Staff Members

One hundred forty-seven respondents answered the age question (see Table D.3). Reported ages ranged from 20 to 70 with a mean of 47 years. Among the respondents, only 38 reported an age below 40 years.

Respondents from the OAS tended to be older than other respondents. Differences were significant at the 99.9 percent level.

Workweeks of NTSB Technical Staff Members

One hundred thirty-five respondents answered the workweek question (see Table D.4). OAS staff estimated a longer workweek than other respondents. Differences in the workweeks reported by OAS respondents

Table D.2
Total Professional Experience, in
Years, Reported by OAS and Other
Respondents

	OAS	Others
Responses	58	90
Mean experience (years)	23.0	19.0
Median experience (years)	25.0	22.0
Standard deviation (years)	10.6	11.5
95% confidence interval (years)	2.7	2.4

Table D.3
Ages Reported by OAS and Other Respondents

	OAS	Others	All Respondents
Responses	58	89	147
Mean age (years)	50.0	44.0	47.0
Median age (years)	51.0	46.0	48.0
Standard deviation (years)	9.2	10.6	10.4
95% confidence interval (years)	2.4	2.2	1.7

Table D.4
Reported Workweeks for the OAS and Other Respondents

	OAS	Others	All Respondents
Responses	55	80	135
Mean workweek (hours)	49.8	46.0	47.5
Median workweek (hours)	50.0	45.0	46.5
Standard deviation (hours)	6.3	7.9	7.5
95% confidence interval (hours)	1.7	1.7	1.3

and other respondents were statistically significant at a greater than 99 percent confidence level.

Differences in Workweeks by Experience Level

Employees having 15 or more years of experience at the NTSB reported longer workweeks than less-experienced respondents (see Table D.5), who all reported average workweeks of similar length. A total of 135 valid responses reported workweeks and years of experience at the NTSB.

Pairwise comparisons by experience group showed a statistically significant difference in workweeks reported by those respondents having 15 or more years of experience at the NTSB and those who had less experience. Table D.6 shows the probability that responses from the two experience groups are statistically distinct when compared using a t-test. The shaded cells in the table show those pairwise comparisons that are statistically significant. Other pairwise comparisons involving respondents with less experience were not statistically significant.

Table D.5

Reported Average Workweek and Experience at the NTSB

NTSB Experience (years)	Responses	Workweek (hours)			
		Mean	Median	SD	95% CI
0-4	38	46.8	45.5	4.8	1.5
5-9	29	46.3	45.0	8.1	2.9
10-14	35	46.6	46.5	8.8	2.9
15+	33	50.4	50.0	7.5	2.6

Table D.6

Pairwise Comparisons of Workweeks Reported by Experience Groups

NTSB Experience (years)	NTSB Experience (years)		
	15+	10-14	5-9
0-4	98%	9%	26%
5-9	96%	14%	-
10-14	94%	-	-

Percentage of Time Spent Answering Public Inquiries

The survey asked respondents to estimate the percentage of work time spent answering public inquiries concerning such areas as accident

theories and safety ideas. Interviews with some members of the technical staff suggested that this activity was interfering with their ability to perform their other duties. The mean time spent answering public inquiries was 6.2 percent for all respondents, corresponding to more than three workweeks per year (see Table D.7).

Table D.7
Reported Percentage of Time Spent Answering Public Inquiries

Responses	149
Mean time answering public inquiries (%)	6.2
Median time answering public inquiries (%)	5.0
Standard deviation (%)	6.6
95% confidence interval (%)	1.1

TRAINING AT NTSB

Percentage of Time Spent Training

The survey asked respondents to estimate the percentage of work time spent in training (see Table D.8). The average across the NTSB was 3.4 percent, corresponding to slightly less than nine days per year of training. OAS respondents estimated they spent less of their time in training than did other respondents. Based on a t-test of the responses, differences were significant at a greater than 99 percent level.

Table D.8
Reported Percentage of Time Spent on Training

	OAS	Others	All Respondents
Responses	58	91	149
Mean time training (%)	2.4	4.0	3.4
Median time training (%)	2.0	4.0	3.0
Standard deviation (%)	1.9	3.5	3.0
Confidence interval 95% (%)	0.5	0.7	0.5

Years of Experience at the NTSB in Relation to Training

Survey responses suggested a monotonically declining trend in the percentage of time spent in training as experience at the NTSB increased

(see Table D.9). Pairwise comparisons by experience group showed a statistically significant difference in time spent in training reported by those respondents having five or fewer years of experience at the NTSB and more experienced respondents. The shaded cells in Table D.10 show those pairwise comparisons that are statistically significant at levels greater than 90 percent. Other pairwise comparisons involving respondents with more experience were not statistically significant.

Table D.9
Reported Training Time and Experience at the NTSB

NTSB Experience (years)	Number of Responses	Mean Time Training (%)
<5	44	4.7
5-9	32	3.3
10-14	38	2.7
15+	35	2.6

Table D.10
Pairwise Comparisons of Training Time Reported by Experience Groups

NTSB Experience (years)	NTSB Experience (years)		
	15+	10-14	5-9
<5	98%	99%	93%
5-9	53%	61%	-
10-14	<1%	-	-

Effect of Workload on Training

Comparisons of actual data collected on training time and overtime expenditures for the technical staff from the OAS showed a negative correlation. Similarly, comparisons of tuition and travel expenses for training and overtime expenditures for NTSB staff members as a whole also showed a negative correlation, suggesting as workloads increased, training tended to decrease. The survey afforded another opportunity to address this issue by examining the relationship between respondents' reported training time and workweek hours.

Survey respondents reporting workweeks of 55 hours or more reported that they spent less time in training than those working fewer hours

(see Table D.11). Pairwise comparisons indicated that training differences among different workweek groups were significant only for the 55-plus hours a week group and groups working 45 to 54 hours per week (see Table D.12). These results suggest that some staff working long hours are training despite having extended workweeks, although that becomes difficult for the longest of workweeks.

Table D.11
Reported Workweek Hours and Training Time

Average Workweek (hours)	Mean Time Training (%)	Number of Valid Responses
<40	2.8	6
40-44	3.3	30
45-49	3.6	37
50-54	3.7	37
55+	2.3	25

Table D.12
Pairwise Comparisons of Training Reported by Workweek Groups

Average Workweek (hours)	Average Workweek (hours)			
	55+	50-54	45-49	40-44
<40	24%	39%	33%	19%
40-44	81%	42%	33%	-
45-49	96%	18%	-	-
50-54	93%	-	-	-

APPENDIX E
RAND SKILLS AND EXPERIENCE QUESTIONNAIRE

This appendix includes a copy of the cover letter that accompanied the RAND *Skills and Experience Questionnaire* and the questionnaire itself. The questionnaire was administered to the NTSB technical staff during the summer of 1998.

August 14, 1998

TO: NTSB Technical Staff
FROM: RAND Institute for Civil Justice
SUBJECT: Distribution of Skills and Experience Questionnaire

RAND is currently performing a study for the NTSB, one element of which focuses on assessing future training needs. The goal is to review current hiring patterns and training initiatives. The study will also examine technological trends in transportation systems with the purpose of identifying any additional skills that will be needed to investigate accidents in the future.

An important element of our research is a survey of current capabilities. This is the aim of the enclosed questionnaire. The questionnaire will help us gain insights into the NTSB as an organization — to identify, in a corporate sense, areas of technical strength and areas where additional hiring and training are required. The results of the questionnaire will help us build an integrated snapshot of the Board today. We are also performing a detailed analysis of training patterns and conducting interviews to understand the perspectives of professional staff members.

The RAND team is sensitive to the fact that questionnaires such as this place an additional burden on already busy schedules. We have attempted to design the questionnaire so as to minimize the time required to fill it out and have asked only for a level of detail needed to support our research. Please note that we are not asking that you identify yourself on the questionnaire. We intend to preserve the anonymity of the information we gather and will present survey data only in aggregate form. The data from this survey could significantly affect our study results, so we ask that your responses be as accurate as possible. To support our study schedule we also ask that you return the survey in the postpaid envelope as early as possible, but no later than September 11, 1998.

We sincerely appreciate your efforts in support of our research,

--- The RAND Team ---

NTSB Skills and Experience Questionnaire

Propriety of Information

This questionnaire is being distributed to acquire an aggregate portrait of NTSB, not to evaluate the skills and experience of individual staff members. RAND will maintain survey information as confidential. RAND will not report individual responses and will present results of the questionnaire in summary form only.

Purpose

As part of a study RAND is performing for the National Transportation Safety Board, we would like to learn more about your skills and experience related to investigating transportation system accidents. The information we seek is in part general, regarding your education and training in preparation for the job, as well as your continuing education on the job. Much of this is technical, regarding the various skills you have acquired in the design and operation of transportation systems. We estimate that it should take about 15 minutes of your time to complete the questionnaire. When you have completed the questionnaire, please return it in the enclosed envelope.

If you have any questions about the questionnaire, please feel free to contact Mr. Emile Ettedgui at RAND: (202) 296-5000, ext. 5268 [Emile_Ettedgui@rand.org]

Structure

The questionnaire is laid out in two parts. This first part contains questions to help us identify your professional status at NTSB and the portion of your time devoted to key aspects of your assignment. The second half of the questionnaire is a skills and experience matrix that will help us understand the distribution of NTSB capabilities. This information will greatly assist RAND in the evaluation of future NTSB training requirements.

PART I Questions

DIRECTIONS:

Answer each question.

POSITION AND BACKGROUND

1. What are your NTSB mail routing symbol and organization code ?
example RE - 1 0 4 1 0 0
2. Do you occupy a management position at NTSB (office director or deputy director, regional director, division or field chief,...) ?
Yes ☐ No ☐
3. Where did you work prior to joining NTSB (if hired from school check "Academia")?
 - ☐ Government agency
 - ☐ Industry check one
 - ☐ Academia
 - ☐ Military
 - ☐ Other

4. a. Technical/vocational training (*check all that apply*)

- ☐ Technical speciality (e.g. airframe/powerplant mechanics, locomotive engineer,...)
specify:
- ☐ Associate degree
specify:
- ☐ Other
specify:

b. Bachelor's degrees (*check all that apply*)

- ☐ Engineering Specify degree:
- ☐ Physical sciences or mathematics
- ☐ Biological sciences
- ☐ Social and behavioral sciences
- ☐ Business/Management
- ☐ Other (*please specify*)

c. Advanced degrees (*check all that apply*)

- ☐ Engineering Specify degree:
- ☐ Physical sciences or mathematics
- ☐ Biological sciences
- ☐ Social and behavioral sciences
- ☐ Business/Management
- ☐ Law
- ☐ Medicine
- ☐ Other (*please specify*)

5. How many years of experience do you have as a transportation professional?

6. How many years have you worked at NTSB?

7. What is your age?

PROFESSIONAL DEVELOPMENT

8. In your opinion, is there enough time to obtain training to maintain and improve your professional skills?

Yes ☐ No ☐

... your investigative skills?

Yes ☐ No ☐

9. During the past year, could you help us better understand how you spent your time? Please estimate the fraction of time spent in each of the following categories (to add to 100%). If you have not been at the NTSB for an entire year, give the percentages to date.

Investigations of specific accident (within your office)

- ☐ On-scene investigations of specific accident (in the field or away from your office)
- ☐ Writing investigative reports
- ☐ Answering public inquiries (including accident theories, safety concepts, etc...)
- ☐ Safety studies not tied to a single accident investigation
- ☐ Participation in hearing or legal proceedings
- ☐ Office and administrative tasks (incl. meetings not related to investigations)
- ☐ Training and professional development
- ☐ Leave (vacation, sick,...)
- ☐ Other (please specify)

100% **TOTAL**

10. Please estimate (based on your experience of the past year) the number of hours, on average, you worked during a representative week to accomplish your NTSB assignments, including time worked in excess of 40 hours as appropriate.

11. During the past year, in which of the following professional development activities have you participated to enhance your accident investigation skills and/or your technical knowledge in your area of specialty? Please include only those activities in which professional development was the primary goal and not a byproduct of your participation.

(check all that are applicable)

	<i>To develop specific skills in your discipline</i>	<i>To develop new professional skills outside your discipline</i>
Formal in house training programs (including writing and management)	<input type="checkbox"/>	<input type="checkbox"/>
Structured mentoring at NTSB	<input type="checkbox"/>	<input type="checkbox"/>
Training by consultants to NTSB	<input type="checkbox"/>	<input type="checkbox"/>
NTSB seminars	<input type="checkbox"/>	<input type="checkbox"/>
University courses toward degree	<input type="checkbox"/>	<input type="checkbox"/>
University courses for continuing education	<input type="checkbox"/>	<input type="checkbox"/>
Professional society meetings	<input type="checkbox"/>	<input type="checkbox"/>
Training programs or seminars from manufacturer	<input type="checkbox"/>	<input type="checkbox"/>
Training programs or seminars from operators	<input type="checkbox"/>	<input type="checkbox"/>
Training programs or seminars from trade groups	<input type="checkbox"/>	<input type="checkbox"/>
Training from U.S. or foreign government agencies	<input type="checkbox"/>	<input type="checkbox"/>
Temporary employee exchanges	<input type="checkbox"/>	<input type="checkbox"/>
Other <input type="text"/>	<input type="checkbox"/>	<input type="checkbox"/>

PART II Skills and Experience Inventory

DIRECTIONS:

ALL respondents should fill out the “Accident Investigation” section. Fill out additional sections (or parts of sections) in all areas where you feel you have relevant skills and experience. Rank your expertise from 1 to 5 in each category according to the qualitative measures on the right. If you have no skills or experience for a given item leave it blank.

1

PASSING KNOWLEDGE

- Few hours of training, or
- Conversant, but never apply knowledge in practical context

2

LIMITED KNOWLEDGE

- Some formal training
- Rarely called on to apply the knowledge

3

MODERATE KNOWLEDGE

- Professional training in this area
- Occasionally called on to apply knowledge

4

EXTENSIVE KNOWLEDGE

- Maintain currency through training and self-education
- Regularly apply knowledge in accomplishing job

5

EXPERT

- Could teach the subject area
- Rich set of skills and experience sufficient to lead others

ACCIDENT INVESTIGATION

A. Planning and Implementation

Project management (planning, scheduling, budgeting, personnel relations,...)	1	2	3	4	5
Professional communication:					
Public speaking/public relations	1	2	3	4	5
Technical writing	1	2	3	4	5
Technical presentation	1	2	3	4	5
Family liaison	1	2	3	4	5
Media relations	1	2	3	4	5
Foreign language skills	1	2	3	4	5
Management of investigations:					
Coordination of parties (incl. rules of party process, information control,...)	1	2	3	4	5
Recovery and wreckage security	1	2	3	4	5

B. Analysis and Evaluation

Investigative procedures:					
Interviewing techniques	1	2	3	4	5
Evidence gathering and protection	1	2	3	4	5
Data cataloging and archiving	1	2	3	4	5
Wreckage recovery	1	2	3	4	5
Reconstruction and crash simulation	1	2	3	4	5
Failure analysis:					
Fracture mechanics	1	2	3	4	5
Corrosion failure causes	1	2	3	4	5
Matrix composite failure modes	1	2	3	4	5
Foreign object damage	1	2	3	4	5
Testing (nondestructive testing, fault isolation, etc...)	1	2	3	4	5
Systems analysis (incl. fault tree analysis)	1	2	3	4	5

Investigative science:					
Accident kinematics	1	2	3	4	5
Crash simulation	1	2	3	4	5
Accident reconstruction	1	2	3	4	5
Combustion and accident related fires	1	2	3	4	5
Explosives and taggants	1	2	3	4	5
Ballistics	1	2	3	4	5
Chemical analysis and assay	1	2	3	4	5
Toxicology	1	2	3	4	5
Forensic pathology	1	2	3	4	5
Data recovery and analysis (incl. transcription, FDR/CVR teardown, radar	1	2	3	4	5
Human performance factors:					
Group dynamics and team performance	1	2	3	4	5
Cognitive processes/decision-making	1	2	3	4	5
Crisis response, disorientation, task overload, workload factors	1	2	3	4	5
Drug-induced impairment (intoxicants, etc...)	1	2	3	4	5
Physiological factors (sleep deprivation, fatigue, etc...)	1	2	3	4	5
Human/machine interactions, automation	1	2	3	4	5
C. Legal Aspects of Accident Investigations					
Tort liability practices and procedures	1	2	3	4	5
Legal aspects of investigations:					
Selection of parties	1	2	3	4	5
Role of parties (including conduct)	1	2	3	4	5
Investigation authority and protocols	1	2	3	4	5
The litigation process:					
Role of technical/expert witnesses	1	2	3	4	5
Admissibility of NTSB report and factual findings	1	2	3	4	5
Deposition and trial procedures	1	2	3	4	5
Role of insurers	1	2	3	4	5

DIRECTIONS:

For sections (1) through (6), fill out sections and subsections in areas where you feel you have relevant skills.

(1) AVIATION SYSTEMS

A. Aircraft Design

Aerodynamics/stability and control	1	2	3	4	5
Structure and airframe:					
Construction techniques	1	2	3	4	5
Joinery	1	2	3	4	5
Metals and alloys	1	2	3	4	5

Composites	1	2	3	4	5
Plastics	1	2	3	4	5
Paints and anti-corrosion coatings	1	2	3	4	5
High temperature materials	1	2	3	4	5
Propulsion:					
Turbine	1	2	3	4	5
Reciprocating	1	2	3	4	5
Propellers	1	2	3	4	5
Engine/airframe integration	1	2	3	4	5
Rotorcraft propulsion systems (incl. transmissions, rotor rigging,...)	1	2	3	4	5
Flight control systems:					
Mechanical and servomechanical	1	2	3	4	5
Fly-by-wire	1	2	3	4	5
Flight control software	1	2	3	4	5
Aircraft operating systems:					
Hydraulics and pneumatics	1	2	3	4	5
Landing gear, wheel, brakes, tires	1	2	3	4	5
Fuel systems (storage, distribution, measurement, etc...)	1	2	3	4	5
Auxiliary power systems	1	2	3	4	5
Electrical/power systems	1	2	3	4	5
Environmental control (including oxygen systems)	1	2	3	4	5
Emergency and egress systems	1	2	3	4	5
Malfunction reporting and recording equipment (FDR, CVR, ELT, etc...)	1	2	3	4	5
Fire detection/suppression systems	1	2	3	4	5
Crew station engineering (instrumentation, flight deck automation, crew systems)	1	2	3	4	5
Avionics:					
Communications	1	2	3	4	5
Navigation (incl. GPS, INS, GPWS, TCAS landing aids,...)	1	2	3	4	5
Autopilot systems (including flight computers, auto-throttles,...)	1	2	3	4	5
Radar systems	1	2	3	4	5
Flight dynamics modeling and simulation	1	2	3	4	5
B. Aircraft Operations					
Ground operations:					
Maintenance and inspection	1	2	3	4	5
Repair and modification (including standards and regulations)	1	2	3	4	5

Loading and cargo handling (including weight and balance)	1	2	3	4	5
Ground servicing (including deicing procedures)	1	2	3	4	5
Airline flight operations (air carrier planning, operations, etc...)	1	2	3	4	5
Crew procedures (routine, emergency, instrument flight, etc...)	1	2	3	4	5
Training and simulation:					
Flight crew training	1	2	3	4	5
Ground and maintenance crew training	1	2	3	4	5
Air traffic management training	1	2	3	4	5
Air traffic management/control procedures (terminal, en-route, ground etc...)	1	2	3	4	5
Atmospheric effects (icing, precipitation, turbulence, windshear, etc...)	1	2	3	4	5

(2) MARINE SYSTEMS

A. Ship Design

Hydrodynamics and stabilization	1	2	3	4	5
Freight and containerized cargo	1	2	3	4	5
Liquid and LNG transports	1	2	3	4	5
Passenger ships	1	2	3	4	5
Event recording systems	1	2	3	4	5
Propulsion (diesel, diesel-electric, nuclear, turbine, fueling, etc...)	1	2	3	4	5

B. Sea Operations

Navigation (GPS, Loran, port procedures, hazard avoidance)	1	2	3	4	5
Communications	1	2	3	4	5
Emergency procedures (lifeboats, etc...)	1	2	3	4	5

(3) RAIL SYSTEMS

A. Rail Systems Design

Modeling and simulation:					
Track-train dynamics	1	2	3	4	5
In-train force	1	2	3	4	5
Locomotives:					
Diesel	1	2	3	4	5
Electric	1	2	3	4	5
Transit systems:					
Self-propelled units	1	2	3	4	5
Light rail vehicles	1	2	3	4	5
Cable cars	1	2	3	4	5
Commuter cars	1	2	3	4	5

Railroad car:					
Structural design	1	2	3	4	5
Repair and maintenance	1	2	3	4	5
Braking systems:					
Air brakes	1	2	3	4	5
Transit	1	2	3	4	5
Track design and repair	1	2	3	4	5
Control systems:					
Propulsion	1	2	3	4	5
Brakes	1	2	3	4	5
Fault monitoring and warning systems (incl. fire detection and suppression)	1	2	3	4	5
Signaling:					
Train control systems	1	2	3	4	5
Cab signals	1	2	3	4	5
Automatic train stop systems	1	2	3	4	5
Wayside systems	1	2	3	4	5
Communications:					
Radio	1	2	3	4	5
Telemetry systems	1	2	3	4	5
Defect detectors	1	2	3	4	5
Event recording systems	1	2	3	4	5
B. Rail Operations					
Maintenance and repair:					
Locomotives and self-propelled systems	1	2	3	4	5
Cars	1	2	3	4	5
Track and infrastructure (incl. bridge, tunnel, trestle inspection,...)	1	2	3	4	5
Regulation/Certification (incl. operator certification, FRA, FTA, APTA standards,...)	1	2	3	4	5
Train handling	1	2	3	4	5
Dispatching and scheduling	1	2	3	4	5
Terminal operations	1	2	3	4	5
Securement of lading	1	2	3	4	5
Crew operations (work-rest cycles, training, testing,...)	1	2	3	4	5

(4) HIGHWAY SYSTEMS

A. Highway Design and Construction

Vehicle design:					
Cars and light trucks	1	2	3	4	5
Heavy trucks	1	2	3	4	5
Passenger and school buses	1	2	3	4	5
Emergency and specialty vehicles	1	2	3	4	5

Vehicle operations:					
Maintenance and repair	1	2	3	4	5
Operator procedures	1	2	3	4	5
Environmental effects	1	2	3	4	5
Safety systems (incl. air bags, anti-lock brakes, seat belts, child restraints,...)	1	2	3	4	5
Grade crossings:					
Design and operation	1	2	3	4	5
Maintenance	1	2	3	4	5
Regulatory/civil engineering standards	1	2	3	4	5
Bridges and overpasses:					
Design and construction	1	2	3	4	5
Maintenance and repair	1	2	3	4	5
Regulatory/civil engineering standards	1	2	3	4	5

(5) PIPELINE SYSTEMS

A. Pipeline Design and Construction

Directional drilling technology	1	2	3	4	5
Material properties and failure mechanisms	1	2	3	4	5
Pipeline systems and components:					
Natural gas	1	2	3	4	5
LNG	1	2	3	4	5
Liquids	1	2	3	4	5
Distribution and transmission networks	1	2	3	4	5
Storage facilities	1	2	3	4	5
Corrosion protection systems technology	1	2	3	4	5
Odorization technology	1	2	3	4	5
Risk analysis	1	2	3	4	5

B. Pipeline Operations and Maintenance

Operations:					
General operating requirements and procedures	1	2	3	4	5
SCADA systems	1	2	3	4	5
Inspection and testing requirements/standards (incl. non-destructive testing)	1	2	3	4	5
Training requirements	1	2	3	4	5
Maintenance:					
Leak detection and repair	1	2	3	4	5
Component maintenance and repair (incl. corrosion control)	1	2	3	4	5
Safety:					
Public education	1	2	3	4	5
Damage prevention programs	1	2	3	4	5

Pipeline locating	1	2	3	4	5
Failure investigation and reporting	1	2	3	4	5
Emergency plans	1	2	3	4	5
Fire detection / prevention systems	1	2	3	4	5
Facility security	1	2	3	4	5

(6) HAZARDOUS MATERIALS

Material properties and failure mechanisms	1	2	3	4	5
Design and maintenance of hazardous material containers (incl. non-destructive testing):					
Rail	1	2	3	4	5
Highway	1	2	3	4	5
Air	1	2	3	4	5
Marine	1	2	3	4	5
Tank technology (incl. coatings/linings, pressure cylinders,...)	1	2	3	4	5
Requirements and standards:					
UN performance standards	1	2	3	4	5
Packaging and labeling	1	2	3	4	5
Cargo transport and transfer	1	2	3	4	5
Substance detection and identification	1	2	3	4	5
Risk analysis	1	2	3	4	5
Safety:					
Fire detection / prevention systems	1	2	3	4	5
Routing	1	2	3	4	5
Emergency plans/evacuation/survival factors	1	2	3	4	5

ADDITIONAL COMMENTS

If you have any further comments on any skill or experience areas missing from the survey that you regard as important, please make them here and on the back of this page.

APPENDIX F
CASE STUDY ABSTRACTS

Examination of seminal accidents was an essential element of RAND's research methodology. Six accidents were selected for detailed study, including a review of factual and Final Reports (when available), probable cause formulations, and the challenges presented to the investigative teams.

Four of the case study accidents had been completed prior to the start of RAND's research, as is noted in the following sections. For the TWA Flight 800 study, the RAND team visited the reconstruction site and reviewed extensive materials used during the ongoing investigation. The USAir Flight 427 investigation concluded during the course of RAND's research, allowing the team to view firsthand the final NTSB Board hearing and the activities of investigators during the preparation of the draft Final Report. The following abstracts of the accidents were taken from official NTSB reports.

COMAIR FLIGHT 3272--COMPLETED

At about 3:54 p.m. Eastern Standard Time on January 9, 1997, an Empresa Brasileira de Aeronautica, S/A EMB-120RT, N265CA, operated by COMAIR Airlines, Inc., as Flight 3272, crashed during a rapid descent after an uncommanded roll excursion near Monroe, Michigan. Flight 3272 was being operated under the provisions of Title 14 CFR Part 135 as a scheduled, domestic passenger flight from the Cincinnati/Northern Kentucky International Airport, Covington, Kentucky, to the Detroit Metropolitan/Wayne County Airport, Detroit. The flight departed Covington at about 3:08 p.m., with two flight crew members, one flight attendant, and 26 passengers on board. There were no survivors. The airplane was destroyed by ground impact forces and a postaccident fire. Instrument meteorological conditions prevailed at the time of the accident, and Flight 3272 was operating on an instrument flight rules flight plan.

DELTA FLIGHT 554--COMPLETED

At about 4:38 p.m. Eastern Daylight Time on October 19, 1996, a McDonnell Douglas MD-88, N914DL, operated by Delta Air Lines, Inc., as Flight 554, struck the approach light structure at the end of the runway deck during the approach to land on Runway 13 at the LaGuardia Airport, in Flushing, New York. Flight 554 was being operated under the provisions of 14 CFR Part 121, as a scheduled, domestic passenger flight from Atlanta to Flushing. The flight departed the William B. Hartsfield International Airport at Atlanta at about 2:41 p.m., with two flight crew members, three flight attendants, and 58 passengers on board. Three passengers reported minor injuries; no injuries were reported by the remaining 60 occupants. The airplane sustained substantial damage to the lower fuselage, wings (including slats and flaps), main landing gear, and both engines. Instrument meteorological conditions prevailed for the approach to Runway 13; Flight 554 was operating on an instrument flight rules (IFR) flight plan.

SIMMONS FLIGHT 4184 (ROSELAWN)--COMPLETED

On October 31, 1994, at 3:59 p.m. Central Standard Time, an Avions de Transport Regional, Model 72-212 (ATR 72), registration number N401AM, leased to and operated by Simmons Airlines, Incorporated, and doing business as American Eagle Flight 4184, crashed during a rapid descent after an uncommanded roll excursion. The airplane was in a holding pattern and was descending to a newly assigned altitude of 8,000 feet when the initial roll excursion occurred. The airplane was destroyed by impact forces; and the captain, first officer, two flight attendants, and 64 passengers died. Flight 4184 was a regularly scheduled passenger flight being conducted under 14 CFR Part 121, and an IFR flight plan had been filed.

TWA FLIGHT 800--INVESTIGATION IN PROGRESS

On July 17, 1996, at 8:31 p.m. Eastern Daylight Time, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about eight miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport. All 230 people on board were killed. The airplane was being operated as a 14 CFR Part 121 flight to Charles De Gaulle

International Airport at Paris as Trans World Airlines (TWA) Flight 800. The last transponder altitude reported by air traffic control radar was 13,700 feet and the captain's altimeter was found fixed at slightly more than 13,820 feet. Wreckage from the airplane was recovered from more than nine square miles of ocean area. Reconstruction of portions of the wreckage found evidence of an explosion in the center wing fuel tank, and parts from the fuel tank were among the first found along the debris trail.

USAIR FLIGHT 427--COMPLETED

On September 8, 1994, at 7:04 p.m. Eastern Daylight Time, USAir Flight 427, a Boeing 737-3B7 (737-300), N513AU, crashed while maneuvering to land at Pittsburgh International Airport, Pittsburgh. The airplane was being operated on an IFR flight plan under the provisions of 14 CFR Part 121, on a regularly scheduled flight from Chicago to Pittsburgh. The airplane was destroyed by impact forces and fire near Aliquippa, Pennsylvania. All 132 persons on board were killed.

VALUJET FLIGHT 592--COMPLETED

On May 11, 1996, at 2:13 p.m. Eastern Daylight Time, a Douglas DC-9-32 crashed into the Everglades about 10 minutes after takeoff from Miami International Airport, Miami. The airplane, N904VJ, was being operated by ValuJet Airlines, Inc., as Flight 592. Both pilots, the three flight attendants, and all 105 passengers were killed. Visual meteorological conditions existed in the Miami area at the time of the takeoff. Flight 592, operating under the provisions of 14 CFR Part 121, was on an IFR flight plan destined for the William B. Hartsfield International Airport, Atlanta.

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