

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.