SAFETY IN FLIGHT has been a concern of many people reaching back for many, many years. In fact, the first mention of an airman fatality and the first probable cause of an aviation accident appears in Greek Mythology. You probably will recall that Daedalus, who was an architect, carpenter, and inventor had incurred the wrath of the King of Crete and had been imprisoned. In order to escape, he fashioned a pair of wings of feathers and wax for himself and his son Icarus. Together they attempted a flight to Sicily. En route, however, Icarus' wings failed, and he fell into the Icarian Sea. The story does not tell us who the investigators were, but I am sure they must have felt some of the same frustration we do when the hardware we need to examine is under hundreds of feet of water. Notwithstanding this handicap, the officials apparently completed their investigation and concluded that this was a pilot error accident, precipitated when Icarus flew too close to the sun, thus causing the wax bonding of his wings to melt. The pilot error conclusion was influenced no doubt by the fact that Daedalus made it safely to Sicily, where he lived a long life and built many temples. Presumably, Icarus could have made it to Sicily also if he had not attempted to set an altitude record on the way.

I am quite sure that if the National Transportation Safety Board had investigated that accident it would not have so easily concluded that the probable cause was pilot error. I believe that we might have made some comments on the suitability of wax as a bonding material, or at least recommended accident prevention measures such as provision for maximum operating altitudes or minimum distances from the sun when wax was used as a structural fastener. Whatever the true circumstances may have been, the story of Icarus is ancient, but the history of the National Transportation Safety Board is in a way just beginning, and I would like to take a moment to identify the Board, or the NTSB as it is sometimes called, before discussing our accident investigation and accident prevention procedures.

II. THE NATIONAL TRANSPORTATION SAFETY BOARD

The National Transportation Safety Board was created by the Department of Transportation Act and began operations officially in April of 1967. While the Board is established within the framework of the Department of Transportation for certain administrative and support purposes,
the Act specifically provides that it shall be independent of the Secretary and other officers or offices of the Department of Transportation in the exercise of its powers and duties. In fact, accident investigation decisions the Board makes are not reviewable, and its certificate appeals decisions are reviewable only by the courts.

Under the provisions of the Department of Transportation Act, the National Transportation Safety Board is charged with responsibility for the investigation and probable cause determination of transportation accidents. Its safety activities thus extend into civil aviation, marine, railroad, highway and pipeline modes of transportation. In the course of these activities the Board’s primary objective is accident prevention. In fact, a review of the legislative history of the Department of Transportation Act of 1966 shows this to be a mandate from Congress. Accident investigation, special studies, and statistical analyses are the principal tools used in achieving this objective.

Under the Act of 1966, the Bureau of Safety of the Civil Aeronautics Board was transferred intact to the National Transportation Safety Board and became its Bureau of Aviation Safety. The duties and functions were not changed in the transfer, and it is this Bureau that is responsible for the conduct of investigations of accidents involving civil aircraft in the United States. To carry out its duties the Bureau maintains a Washington headquarters, and eleven field offices strategically located throughout the United States. The Bureau has a total complement of 184 employes comprised of 52 field investigators, 55 Washington-based investigators, and 77 technical specialist, administrative, and clerical personnel. The investigation staff contains specialists in such diverse fields as meteorology, metallurgy, aircraft systems and structures, powerplants, electronics, aircraft maintenance, piloting and air traffic control.

III. THE INVESTIGATION BY THE BOARD

Investigations conducted by the Bureau follow much the same management pattern whether the investigation involves a small general aviation accident and is conducted by a field office investigator or whether a catastrophic air carrier accident investigation is being conducted by a Washington headquarters team. The principal difference lies only in the complexity of the investigation and the number of the participating parties involved.

It should be noted here that the purpose of the Board’s investigation is to determine probable cause of the accident, not to assess liability. To coin a phrase, we investigate airworthiness, not blameworthiness. Further, we do not investigate accidents simply in order to remove the mystery surrounding the crash or to satisfy public curiosity; it is the fulfillment of a public service under the mandates of Congress. The purpose of our investigation is to obtain all relevant knowledge so that appropriate corrective measures may be taken to prevent similar accidents in the future. Accurate cause determination is the major contribution in this endeavor. When the Board finds safety problems warranting further attention by the FAA, other government agencies or industry, recommendations are formulated. These
recommendations become a matter of public record under the provisions of Section 5(e) of the Department of Transportation Act.

In the investigation of a major air carrier accident, we use a management procedure identified as the “team” concept or specialty group system. Under this plan there are four Washington-based supervisory air safety investigators who are assigned as investigator-in-charge on a rotating basis. On Friday of each week a “go-team” is established on a standby basis for instant dispatch to the scene of an accident. This team is composed of the investigator-in-charge, two assistant investigators-in-charge, one for airworthiness and one for operations, and a number of specialists assigned as chairmen of the various technical groups. Members of the Board take assignments in rotation so that when the team is activated a Board member is on call to accompany the team to the accident site. When notification of an accident is received by the Board’s duty officer, the assigned team is alerted and a determination to dispatch it is made based on the conditions and circumstances surrounding the accident.

During the same period appropriate FAA personnel are being notified through FAA channels. Members of industry groups who will participate in the investigation are being alerted by their respective organizations. In addition to the FAA, participating parties normally include the following: airframe manufacturer, powerplant manufacturer, equipment manufacturer, the airline operator involved, the Air Line Pilots Association or the Allied Pilots Association, the Flight Engineers International Association, the International Association of Machinists, and the Air Line Dispatchers Association. Additionally, other organizations often participate, depending on the nature and circumstances of the accident or the equipment involved. Examples are: (1) one or more of the military services in such cases as a mid-air collision with a military aircraft or if they operate similar equipment, (2) the United States Weather Bureau, (3) the Federal Bureau of Investigation, (4) the Armed Forces Institute of Pathology, (5) the National Aeronautics and Space Administration, and (6) representatives of a foreign government, under ICAO agreements, if an aircraft of foreign registry or foreign manufacture is involved.

Industry participation is not for the purpose of conferring special privilege on any person or company, but it is to provide the Board with technical knowledge or specialized skills that might be otherwise unobtainable. Additionally, the Board sees an outstanding advantage in permitting these parties to participate. Participation provides an opportunity for a rapid and natural flow of information to the participating organization’s supervisory personnel. This can lead to early, coordinated, corrective action in many areas of design, manufacture and operation of the aircraft and its components. Many such actions are outside the sphere of causal factors but, nevertheless, enhance future safety of operation.

The first order of business upon arrival on scene is an organizational meeting of the Safety Board’s investigators and interested party personnel. Emphasis is placed on locating the flight recorder and cockpit voice recorder. Each of the interested parties has a coordinator assigned to the in-
vestigation. The coordinator is the senior participant for his organization and acts as liaison between the investigation and his parent organization. Each coordinator provides personnel from his organization for assignment by the investigator-in-charge to one or more of the specialty groups in which his organization may be able to provide a high degree of expertise. The chairman of each group is an NTSB investigator who is a specialist in a particular technical area to be covered during the course of the investigation. The number of groups established depends to some extent on the nature of the accident. In general, however, groups would be established for each of the following specialized areas of investigation:

1. aircraft structures,
2. powerplants (and propellers as appropriate),
3. systems,
4. maintenance records,
5. aircraft and company operations procedures,
6. air traffic control,
7. weather,
8. witnesses,
9. human factors, and
10. flight data recorder.

The names of these groups very nearly identify their area of activity; therefore, I will not attempt to spell out their responsibilities at this time. Rather, I would like to give you a few illustrations of how each group, at one time or another through the years, has provided the principal facts upon which the probable cause of the accident could be established.

On 6 January 1960, a DC-6B crashed near Bolivia, North Carolina. While most of the wreckage was found near Bolivia, a sizable portion of the fuselage and the body of a passenger were located 16 miles away. Upon initial examination by the structures group it was obvious that structural separation had occurred in flight. A three dimensional reconstruction of the fuselage and center wing area was made to facilitate the group in its work of piecing together evidence to show how structural separation occurred and where it originated. In examination of the wreckage several of the following possibilities were considered: metal fatigue failure and explosive decompression; propeller blade failure and cabin penetration; malfunction of the cabin pressure system; lightning strike; fuel vapor explosion; oxygen bottle explosion; and the possibility of detonation of a high energy explosive within the cabin.

The three dimensional mock up disposed of all possibilities but that of the presence of a high energy explosive. In the examination of the pieces of wreckage sodium carbonate, sodium nitrate, and complex mixtures of sodium sulphur compounds were found in the passenger cabin air vents. This residue is characteristic of a dynamite explosion. Nitrates were also found on material ejected from the cabin and located 16 miles from the main wreckage. In this instance the structures group assisted by the human factors group was not only able to prove the cause of the structural dam-
In an accident near Chase, Maryland, in 1959, the weather group was able to identify the probability of extreme turbulence in a clear area ahead of a thunderstorm and at the altitude at which the aircraft was operating. This turbulence led to a loss of control and subsequent inflight breakup of the aircraft. The human factors group in this instance, through autopsies detailing injuries to the passengers, provided information that confirmed the presence of the extreme turbulence. Extreme turbulence associated with thunderstorm activity was again identified as having been involved in the more recent accident at Falls City, Nebraska, on 7 August 1966. Incidentally, the accepted definition of extreme turbulence is "a rarely encountered turbulence condition in which the aircraft is violently tossed about and is practically impossible to control. It may cause structural damage."

In the accident involving an F-27 at San Ramon, California, on 7 May 1964, analysis of the air traffic control communications tapes by the ATC identified the fact that the crew had been shot while the aircraft was en route to San Francisco. The more recent crash of the DC-8 at New Orleans on 30 March 1967, was solved in great part by the information derived from the flight data recorder and correlated data from the cockpit voice recorder. These are but a few examples of the many instances in which the final phase of an investigation centers around an area of specific investigative activity.

On rare occasions it may develop that special groups need to be formed; these are handled on an ad hoc basis. These special groups have been instituted to examine such areas as manufacturing processes, overhaul facilities, and aerodynamics.

One very essential key element to accident investigation is flexibility. Many varied factors influence the course of an investigation, e.g., terrain, weather, type of accident (in-flight failure, fire, explosion), and type and complexity of the aircraft and its component parts. There can be no hard and fast rules governing how many groups, numbers of investigators, or the extent of investigation within the groups. Oftentimes during the relatively early stages of an investigation, it is possible to channel the major on-going efforts in particular directions. For example, if the accident involved is a mid-air collision, it is usually possible after a limited amount of investigation to eliminate the powerplants as a causal factor; therefore we do not engage in a detailed disassembly of the engines. The advent of the flight data recorder and cockpit voice recorder have played a major role in facilitating the effective channeling of investigative efforts with a resultant saving in manpower and money. As the foregoing suggests, many groups arrive at a negative finding, i.e., nothing abnormal or unusual was disclosed by their particular part of the investigation. By obversion, this becomes positive information in that by process of elimination the area of probable cause becomes isolated and is brought into sharp focus.

While the Board's procedures for an investigation are well established,
the success of our operations are often associated with innovation. The very nature of our work places a premium on individual initiative and imagination. For example, in the accident involving the Lockheed Electra that crashed into the bay at Boston in 1960, it became necessary to determine if power was being produced on a particular engine. We knew that the engine in question was the source of energy for certain electronic equipment aboard the aircraft. Consequently, a rather unique test was employed using vacuum tubes identical to those contained in the accident-involved electronic component being examined. The vacuum tubes were heated to operating temperature and immersed in water elevated to a temperature of $57^\circ$, the same temperature as that of the accident site in Winthrop Bay at Boston. The vacuum tubes in the accident aircraft had cracked or crazed in a specific manner whereas the unheated tubes did not display the same pattern. This test provided further confirmation of the fact that the engine in question had in fact been developing power and that the electronic equipment in question had been in operation at the time of impact.

In other circumstances, we have been comparatively successful in using the cockpit voice recorder tapes to determine such things as aircraft speed and in one instance the overspeed condition of a propeller just prior to its failure. This has been accomplished by analyzing the frequency and amplitudes of the noise recorded on the CVR. While this device was conceived and designed originally to provide a record of crew conversations, it has proved immeasurably valuable in other instances similar to those just described.

During many accident investigations, laboratory studies of failed components or materials associated with the aircraft are required to obtain information related to the cause of the accident. The Board maintains a small metallurgical laboratory in Washington for the purpose of making such studies. This laboratory conducts our routine metallurgical investigations, but it does not have the facilities for many of the specialized studies required. Work such as the examination of fractures with electron microscope, spectographic identification or analysis of materials, the determination of the extent of deterioration of non-metallic materials, and more extended research or testing programs is done for the Board in other government or industry laboratories. The National Bureau of Standards, the FBI, the Naval Research Laboratory, and many aviation industry laboratories conduct special studies for the Board. In all cases, however, when components are retained by the Board for laboratory study, the custody of the parts is controlled by the Board until they are returned to the owner after the Board's investigation is completed.

In order to expedite corrective action it is the general practice of the Board to cooperate as much as possible with manufacturers who desire to make their own laboratory investigation of failed components. For this reason one half of a broken part is frequently sent to the manufacturer and the other half retained by the Board for laboratory study. Keep in mind that the mated surfaces of a failed part are mirror images, and either surface will tell the identical story.
In many cases evidence may be destroyed during the course of the laboratory investigations. Parts frequently must be cut through a fracture origin, for example, to determine the cause of failure. However, the evidence is always documented to the ultimate extent possible by photography or other means.

The factual information that the Board develops is recorded and made into a public record. When a public hearing is not held, this record is composed of the factual reports of the investigator-in-charge and those of any specialty group chairman who may participate in the investigation. Embodied in these reports or contained in the accident file as separate but related factual information will be witness statements, transcripts of air traffic control communications, the results of any special tests or metallurgical examination, photographs, and other pertinent material. All of this information is available to the public in two ways. The record may be reviewed in person in the Board's Washington headquarters or it will be reproduced and mailed on request for a fee, the amount of which is based mainly upon the number of printed pages and photographs copied.

IV. THE HEARING

When a catastrophic air carrier accident occurs a public hearing is usually held. A recent trend is to hold these hearings in Washington. Hearings are fact finding in nature and are not adversary proceedings. Therefore, procedural rules preclude participation of representatives of litigation interests. Hearings are conducted by a board of inquiry which is normally composed of a Board member, a representative of the director's office of the Bureau of Aviation Safety, the hearing officer assigned to the investigation, and a representative of the Board's general counsel. A technical panel is also formed consisting of the investigator-in-charge and those group chairmen necessary to fulfill objectives of the hearing. Primary questioning of witnesses is by the technical panel and the board of inquiry. The parties to the investigation are permitted additional questioning of witnesses, but cross-examination in the legal sense is not allowed. Litigation attorneys may attend these inquiries as members of the public, but they may not participate in the proceedings in any way. The factual reports, together with photographs, charts, drawings, witness statements, laboratory reports and other documentary products of the investigation are introduced into evidence. All questioning and testimony is recorded and becomes a part of the public docket.

The entire factual record, including all exhibits entered, and the transcript of the testimony taken during a hearing is available to the public in the same manner as previously mentioned. In addition, the transcript of the testimony at a public hearing is available from the recording service contractor to anyone who wishes to purchase it. Purchase arrangements can

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1 Copies of material ordered are mailed and billed direct by Graphic Craftsmen, Inc., a Washington business firm holding the current contract for commercial reproduction of the Board's public files. Charges average 15 cents a page for photostatic copies of documents and 90 cents a page for pictures, plus postage ($1 minimum). Orders for this material will also involve a $2 user service charge by the Board. This is in addition to the cost of commercial reproduction of material.
be made from the recorder at the time of the hearing, or the transcript
can be ordered from the recording company at the established fee. The
Board publishes the results of its investigations in the following two forms:
Aircraft Accident Reports (long form) and Briefs of Accidents (short
form). Aircraft Accident Reports are detailed, individual reports of the
facts, circumstances, and probable cause of major aircraft accidents usually
those involving a public hearing. Briefs of Accidents contains the reports
of United States civil aircraft accidents in an abbreviated format. It is
published monthly and provides identifying facts, probable cause and re-
lated factors as well as summary statistical data. In addition, the National
Transportation Safety Board publishes the results of special studies in re-
ports such as Aircraft Design Induced Pilot Error, The Phenomenon of
Aircraft Aquaplaning, and Metal Fatigue and Its Recognition.

All of these reports as well as a wealth of related aircraft accident sta-
tistical information is available to the public. Some documents are free; for
others there is a nominal charge. I will not take the time to detail them all
here, but a list of all publications of the Board containing a description of
the material and its cost is available.

V. ACCIDENT PREVENTION

Fundamentally, what we have discussed up to this point is the present
state of the art of aircraft accident investigation. These procedures have
been for the most part an empirical development over the years that in a
very real sense represent after-the-fact accident prevention. As successful
as this approach to safety has been, the National Transportation Safety
Board believes that the larger mandate given to it by Congress is the pre-
vention of accidents before-the-fact. In this regard, it is interesting to note
that in every legislative act from the Civil Aeronautics Act of 1938, which
created the old Air Safety Board, through the Federal Aviation Act of
1958, which created the Federal Aviation Agency, and into the Depart-
ment of Transportation Act, which created the National Transportation
Safety Board, there has been nearly identical language requiring the suc-
cessive safety agencies to ascertain what will best tend to reduce or elimi-
nate the possibility of accidents by conducting special studies on matters
pertaining to safety and the prevention of accidents.

We are presently taking steps to more effectively discharge our respon-
sibilities and duties in this most important activity. One major step in this
direction is the very recent reorganization of our Bureau of Aviation Safe-
ty and the establishment of an Accident Prevention Branch. This Branch
is responsible for developing and executing accident prevention programs
that will include such diverse activities as human engineering studies rela-
tive to structural design interactions with human performance capabilities,
the computer processing of accident reports, and statistical trend analyses.

We believe that statistical analyses made in a manner similar to the Safe-
ty Board's recently released Aircraft Design Induced Pilot Error study
(ADIPE as it has become more commonly known) can be very effective in
accident prevention. I am sure that all of you are familiar with the seg-
mented pie graphical display that has been prepared by the Bureau for many years. We think that the most interesting aspect of these pictorial presentations is that the percentage figures ascribed to the various causal factors such as pilot error, mechanical deficiencies, or inadequate maintenance have changed but little through the years. What these figures tell us is that we have known for a long time what was happening and that no dramatic reduction in the accident and fatality rates has occurred. We are now of the opinion that a bulk look at all of the accidents in each section of our statistical pie, in the manner of the ADIPE study, will be very productive of accident prevention measures and will assist us materially in the anticipation and recognition of potentially dangerous situations and the root cause of accidents.

The computer is, of course, the key to studies of this nature. We intend to exploit its memory and data retrieval capabilities to the maximum extent possible, not only in after-the-fact learning from past history but in safety projections for the future. These projections will in part be derived from trend analysis and from studies of incidents which in themselves have not caused an accident but which contain elements that unless corrected could lead to an accident in the future. This is not to say that we will be able to eliminate all after-the-fact investigations since it is unlikely that we will be able to anticipate every new or uniquely hazardous situation. However, as the civil aircraft fleet continues to grow it will be necessary for the Board to concentrate its accident investigative efforts to those areas capable of producing the maximum accident prevention and safety promotion material. As a result, we can foresee the day when the Board of necessity will reduce or even eliminate its direct participation in the investigation of certain types of aircraft accidents which, however interesting they may be from a civil litigation standpoint, nevertheless produce little information of value in the saving of human life. Typical of the accidents in this classification are those in which the pilot inadvertently retracts the landing gear instead of the flaps while taxiing to the terminal or the instance in which a helicopter makes a hard contact with the ground during a practice auto-rotation landing. A desk audit type investigation of such accidents could satisfy any requirement with respect to airworthiness certification of the aircraft, proper maintenance, or crew competence. At the same time the Board would have provided to it the statistical data necessary for the “bulk look” previously mentioned.

In practice the policy of limiting our investigations to those accidents most productive of accident prevention information has already been expressed in the National Transportation Safety Board’s Rules Pertaining to Aircraft Accidents, Incidents, Overdue Aircraft and Safety Investigations. These rules exclude from the definition of aircraft accident such things as damage limited to an engine and damage to landing gear, wheels, tires, brakes, flaps, or wing tips. As time and circumstances dictate it may become necessary for the Board to include other occurrences in this list of excluded events in order to better channel its resources and manpower to more productive pursuits.
In closing, we believe that as important as aircraft accident prevention may have been in the past, it can only become more important in the near future as will our role in accident investigation on a selective basis to provide a sound effective accident prevention actions. We are about to inject into the air carrier inventory aircraft costing in excess of $20 million and capable of carrying nearly 500 people. An accident involving such an aircraft might well assume catastrophic proportions dwarfing, by comparison, previous aviation tragedies. Every effort is being expended by both government and industry today to minimize the likelihood of such a tragedy. We in the Board are endeavoring to define and apply the lessons learned from accident investigations and special safety studies using to the extent possible electronic computers to identify those subtle and elusive common denominators in accident causation. In this increasingly important task, we welcome the on-going cooperative efforts of all concerned in the aviation community.