INCORPORATED AIR SAFETY INVESTIGATORS AUGUST 31, 1964

The Society of Air Safety Investigators

THIRD ANNUAL INTERNATIONAL SYMPOSIUM

"The Future of The Air Safety Investigator"

1972

The Society Of

Air Safety Investigators

THIRD

ANNUAL SEMINAR

THE FUTURE FOR

AIRCRAFT ACCIDENT INVESTIGATORS

Sheraton Park Hotel
Washington, D.C.
October 11-12-13, 1972

SEMINAR PROGRAM COMMITTEE

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THE SOCIETY OF AIR SAFETY INVESTIGATORS

Representatives Attending the International Forum

NAME	AFFILIATION
Abarbanell, Capt. Oded	ELAL Israel Airlines
Adlard, V.J.P.	So. African Airways
Allen, William H.	Trans Safety Institute
Alkov, PhD, Robert A.	Naval Safety Center
Andrews, Frank G.	The Boeing Co.
Andrews, Jerry	Andrews Associates
Anson, Robert	AirClaims
Aoyagi, Stanley	Japan Air Lines
Baker, Dick	NTSB
Bates, Mike	Douglas Aircraft
Becker, William B.	ATA
Berg, Magnus	Swedish Air Force
Berscheidt, Ray	Mitsubishi
Blackburn	Coast Guard
Blair, John	Air Canada
Bruno, Glenn K.	Braniff (Retired)
Burton, Capt. Mel	American Airlines
Buzzard, Bruce	FAA
Caceres, Capt. Gustavo	AVIANCA
Clark, A. J.	Dept. of Transport (Canada)
Clarke, Ronald A.	Metro Police Dept.
Clarke, R. C.	British Aircraft Corp.
Collins, Tom	SASI
Cowser, Capt. R. R.	American Airlines
Dalton, Thomas J.	Bendix Navigation & Control
Davis, Tom	Self-employed
Davis, Paul	Naval Air Test Center
Dieckhoff, Richard H.	U.S.A.U.
Doyle, Bernie	NTSB
Dwyer, Donald W.	FAA
Eck, Carl	ALPA
Edwards, Laurence	Civil Aviation Authority
Erickson, D. G.	NTSB (retired)
Fathollahr, A.	Iran Air
Flaherty, Thomas J.	Detrek, Inc.
Fluet, Joseph	NTSB
Friday, Bonnie	Flight Adjusters Ltd.
Fuchs, Bill	Piper Aircraft
Furr, James A.	Eastern Airlines
Galipault, John B.	Galipault & Associates
Golding, Paul	Toplis & Harding
Gowdy, Rex	--
Graves, Frank	NTSB
Green, Stanley J.	GAMA

Name	Affiliation
Greenwood, Jim	FAA
Gregg, William G.	Bendix
Grim, Paul	FAA
Grimes, Corwin	NTSB
Hannifin, Jerry	Time Magazine
Harja, Arne M.	Sundstrand Data Control, Inc.
Hartung, Dr. Walter M.	Academy of Aeronautics
Harvey, Bill	BAC
Hawkins, Barry J.	Fairchild Industrial Products
Hawley, D. C.	ALPA
Heaslip, Terry	Ministry Transport (Canada)
Hugue, Prater	Boeing
Holbrook, Heber	FAA
Holshouser, W. L.	NTSB
Holstine, Arnold	NTSB
Horn, J. Ralph	FAA
Horst, A. W.	Dukane
Hradecky, RoseMarie S.	ALSSA Safety Commission
Hughes, Patricia C.	SAFE Inc.
Jerome, Jerry	Consultant
Jones, R.	---
Kahn G. M.	Pakistan Airlines
Kahn, Mushir Allam	Pakistan
Kemp, Donald E.	FAA
Kraft, Dr. Conrad L.	The Boeing Co.
Kutzleb, Robert E.	Seward
Lamb, William L.	NTSB
Lederer, Jerry	Flight Safety Foundation
Lee, Donald	Flight Adj. Ltd.
Lewis, Jim	NTSB
Lindebod, Mogens	DALPA (Demark)
Logan, Robert M.	M. O. T. Ottawa
Louderbeck, R. M.	U. S. Army
Masden, Ward	Lord Bissel Brook
McDonald, Capt. John R.	ALPA
McGowan, Fred W.	INA
Miller, Charles	NTSB
Miller, Edward E.	Grumman
Mitchell, B. R.	Askew Adjustment Co.
Mohler, Dr. Stanley R.	FAA
Moore, George S.	FAA
Moore, Col. John F.	SAC
Moore, Nathaniel W.	General Aviation Bendix
Morrison, F. Robert	U. S. C. Institute
Morsch, H. G.	VARIG
Mott, Del R.	ALPA - S & S Division
Mouden, L. Homer	Braniff (retired)
Napier	Coast Guard
Nelmes, Ed	NTSB
Newton, Eric	Dept. of Trade & Industry, U.K.
Nichols, Sue	ALSSA

Name	Affiliation
Orr, Robert George	The Boeing Co.
Panarello, Jr., Guy J.	Panarello Adjustment Co.
Perez, Luis A.	Avianca
Phillips, Samuel M.	Dept. of Army
Pickerel, Dr. Evan	FAA
Prendal, Bjarne	Flight Safety Council
Puccia, George	IAM
Purcell	Pan American Air Force
Quinlivan, William	Lockheed
Rawson	NTSB
Reed, John H.	NTSB
Reemond, John	--
Roberts, Carol	NTSB
Roscoe, Marion	NTSB
Rudich, Robert D.	Air Transportation Consultants
Ryan, James	University of Minnesota
Schmiedt, O. R. I.	VARIG
Schneider, Don	Flight Engineers Int'l
Shortill, James	82nd Airborne Division
Shrout, Jerry A.	AVEMCO Inc.
Smith, Capt. J. D.	United Air Lines
Sorrentino, Albert P.	Royal-Globe Insurance Co.
Speas, R. Dixon	R. Dixon Speas Associates
Staal, Douwe W.	SwissAir
Stauffer, Charles	FAA CE-ACDO-33
Suzuki, T.	Japanese Aviation Insurance Pool
Takley, K. H.	Australian Embassy
Thomas, David D.	Flight Safety Foundation
Tibbs, Ansel M.	FAA
Turner, Charles S.	Fairchild Indistries
Vollborth, Capt. Eduardo	Mexicana Airlines
Votruba, William K.	Pan Am World Airways
Vreeland, James M.	Naval Safety Center
Wansbeek, G. C.	KLM Royal Dutch Airlines
Watts, Russel	I. C. A. O.
Wells, Obed T.	Cessna
Whitehead, George I.	U.S. Aviation Underwriters
Wiesman, E. E.	ALPA
Williams, Edgar	Naval Air Test Center
Williams, Edward R.	Assoc. Aviation Underwriter
Wood, Edward C.	FAA
Wood, Richard H.	USAF
Wolffersdorff, Ed Von	Boeing
Yanowitch, Dr. Robert E.	FAA
Yates, Jr., Andy	Airline Pilots Association

WEDNESDAY, OCTOBER 11, 1972

8:00 a.m.	Registration - Hotel Lobby
8:15 & 8:30 a.m.	Bus Transportation - Hotel to FAA-NTSB Headquarters Building, 800 Independence Ave., S.W.
8:00 a.m.	Registration - Auditorium on 3rd Floor FAA Headquarters Building
9:00 a.m.	Coffee Break
9:30 a.m.	Session 1 - Auditorium Welcome - Donald Kemp, President of SASI Opening Remarks - John H. Reed, Chairman, NTSB Keynote Address - George S. Moore, Associate Administrator for Operations, FAA
10:30 a.m.	Program Plans - Ansel M. Tibbs, Program Co-Chairman
11:00 a.m.	Lunch - Individual Preference
1:00 p.m.	Session 2 - Group A, 8th Floor Conference Room Briefing and Tours of FAA & NTSB Facilities and Laboratories
2:30 p.m.	Coffee Break
3:00 p.m.	Group A, Auditorium Movies: Caution, Wake Turbulence Landing Wx Minimums Investigation Approach to Land ILS Simulator Use in Accident Investigation
1:00 p.m.	Group B, Auditorium Movies: As above

2:30 p.m. Coffee Break

3:00 p.m. Group B, 8th Floor Conference Room

4:00 p.m. Bus Transportation to Sheraton-Park Hotel

7:00 p.m. to
9:00 p.m. Cocktail Party - Hotel

9:00 a.m.	Session 3, Cotillion Room, Sheraton-Park Hotel
	Moderator Chairman - William B. Becker, Asst. Vice President Operations - ATA
	Future Aircraft Accident Investigations - Captain John R. McDonald - ALPA
	Astrolog Program of American Airlines - Captain Mel Burton, Director of Flight Instruction - AA
10:00 a.m.	Coffee Break
10:30 a.m.	Underwater Crash Locator System - Paul Davis, Naval Test Center, Patuxent River, Md.
	Aircraft Wreckage Recovery - Robert E. Kutzleb, Vice President, Seaward
	Question and Answer Period
12:00 N	Luncheon - Delaware Suite
	Speaker - Jerry A. Shrout, AVEMCO Inc.
2:00 p.m.	Session 4, Cotillion Room
	Moderator Chairman - R. Dixon Speas, R. Dixon Speas Associates
	FGS - 70 Flight Guidance System - Nathaniel N. Moore, Engineering Manager, General Aviation Bendix
	Stan (R) Integral Weight & Balance System - Barry J. Hawkins, Fairchild Industrial Products
3:00 p.m.	Coffee Break

3:30 p.m. Role of Laboratory and Nondestructive Testing -

C. Howard Craft, Magnaflux Testing Laboratories

Thomas J. Flaherty, Detrek, Inc.

Question and Answer Period

7:00 p.m. Awards Banquet

Reception - Maryland Suite

Awards Banquet - Virginia Suite

Awards Presentation - Donald E. Kemp, President, SASI

Speaker - Capt. J. D. Smith, Vice President

Operations and Engineering, United Air Lines, Inc.

FRIDAY, OCTOBER 13, 1972

9:00 a.m. Session 5, Cotillion Room

Moderator Chairman - Dr. Walter M. Hartung

President Academy of Aeronautics

Explosive Sabotage in Civil Aircraft - Eric Newton

Chief Investigation Officer, AIB, Great Britain

9:30 a.m. Coffee Break

10:00 a.m. Cockpit Video Crash Recorder -

R. A. Peterson, The Boeing Company

Jerry Andrews

Vision in the Cockpit -

Dr. Conrad L. Kraft, The Boeing Company

Question and Answer Period

12:00 N Luncheon - Maryland Suite

Speaker - Stanley J. Green, Vice President,

General Aviation Manufacturers Association

2:00 p.m. Session 6, Cotillion Room

Moderator Chairman - George I. Whitehead, V.P.

U. S. Aviation Underwriters

Aircraft Nickel - Cadmium Batteries

Edward E. Miller, Group Head for Electrical

Power Systems, Grumman

Crash Aspects of Recent Airline Accident

Dr. Stanley R. Mohler, FAA

3:00 p.m. Coffee Break

3:30 p.m. Psychological Autopsies

Dr. Robert E. Yanowitch, FAA

Life Stresses, Biorythm and Aircraft Accidents

Robert A. Alkov, PhD., Head, Behavioral Sciences

Division - Naval Safety Center, Norfolk, Virginia

Question and Answer Period

Seminar Summation - Russel Watts, I.C.A.O.

5:00 p.m. Adjournment

OPENING REMARKS

JOHN H. REED

Chairman
National Transportation Safety Board

I am pleased to address the opening session of the Third Annual International Seminar of the Society of Air Safety Investigators. I consider this Annual International Seminar as one of the most outstanding forums for the exchange of aviation safety intelligence among specialists in the field.

When contemplating your program theme, "The Future for Aircraft Accident Investigators," it occurred to me that we are in the unique business of dedicating our endeavors to the prevention of accidents, which is really an attempt to put ourselves out of business. Unfortunately, as a practical matter, we are aware that there is a future for our investigators, but we trust that the frequency of their call to duty will be on the decrease; hopefully, because of an increase in effectiveness in both investigative and preventive activities.

Accordingly, today I want to discuss what I consider to be one of the most important transportation safety priorities of the future -- the concept of "First Time Safe" -- as applied to transportation generally, and to air transportation specifically. I can see by the titles appearing in the Program Outline that some practical aspects of that concept will be discussed by several of your distinguished members.

Over the years the public has demonstrated its willingness, or even eagerness, to accept new concepts in transportation systems which offer promises of safe, economical, comfortable, and efficient service. The development of our transportation system into its present configuration has required major investments in the design, expansion, and maintenance of the transportation modes. The total investment, of course, is made by the American people, either through the government by taxation, or by the use of private enterprise transportation services.

Unfortunately, there is yet another price being paid for the transportation system which cannot be considered as an investment. The price is in terms of the costs resulting from the accidents being experienced by the people using the system. For example, in United States air carrier operations during the past five and a half years, there were more than 1,000 fatalities and in general aviation the total is in excess of 7,000 fatalities. The dollar cost for medical care, property damage, wage losses, and administrative costs for insurance claim processing is unknown, not mentioning the nonfatal injuries for which the costs in human suffering cannot be measured.

A significant part of the past and even of the present conceptual approach utilized by many organizations responsible for transportation safety, to remove hazards from the system and to advance the state-of-the art, is based largely on implementing corrections after the accidents have occurred. For example, once a safety problem has been identified as a result of a high incidence of a specific type of accident, or by a single catastrophic accident, that problem is studied, safety research is completed, and a solution is developed. Unfortunately, under this concept, our system is serving as the test specimen, with the people who use the system discovering the hazards by experiencing the accidents. This means in many instances that our safety priorities are determined on the basis of accident frequencies.

This experience, when compared with such projects as the space program, the peaceful uses of atomic energy, and many of our defense systems developments, reveals a noteworthy difference. These systems, unlike transportation, had no prior experience which could be applied to safety problem solving, yet there has been an impressive safety record achieved.

This means that safety had to be designed and built into these systems and then demonstrated through operational testing prior to committing them to use. In other words, a "First Time Safe" concept. Therefore, those systems which included a disciplined, total system approach to safety and applied such techniques as Fault Tree Analysis, failure mode and effect analysis and hazard analysis to the identification of hazards as part of their design and development activities have demonstrated a noteworthy safety record.

We are well aware that the "First Time Safe" concept is not exactly unknown in the aviation industry. I have in mind for example, the design, development and manufacture of the current generation of our wide-bodied jets. Speaking of outstanding safety records, I note that there are now 191 Boeing 747's being flown by 29 carriers, and that since its introduction into commercial service the 747 has not been involved in a fatal accident. The Boeing Company informs us that as of mid-September, the 747 had flown one million hours, which they tell us is the equivalent of one 747 flying day and night for approximately 114 years.

There may still be those who might argue about the money spent on the aforementioned projects in order to achieve the safety records I have noted. To them I offer the following basic points:

<u>First</u>, the costs directly attributable to safety in any of those system development programs most probably represent a relatively small percentage when compared with the total development costs of the system.

<u>Second</u>, accidents are generally much less expensive and less painful to prevent than they are to experience, especially when they happen to you. In fact, hardware replacement costs, together with damages awarded by the courts, can be sufficiently large to force an operator out of business after a single catastrophic accident.

<u>Third</u>, those resources devoted effectively to achieving safety in any system can yield highly productive results in terms of a major reduction in the suffering, personal tragedy, and economic loss that result from accidents, as well as to enhance national prestige.

Finally, nothing worth having ever comes cost-free.

Much of the safety record realized in these programs has come about because there is an established mechanism which assures that the results of the analysis and other data produced by the safety organization are utilized by management as one of the factors considered in making decisions. Some of these decisions ultimately will be either to modify the system to remove the hazard, reduce the probability that the hazard will be activated into an accident, or to accept the risk in areas where the hazard activation probability is low; in other words, management of the risks.

Since there is no system which can ever be completely devoid of some element of risk, it is vital in the operation of the system that the risks be understood and their assumption justified through management of those risks. The role of the manager in risk management includes initially the definition and implementation of the technical safety effort that will produce the risk data in a format which will be useful in the decision-making process. Secondly, he will use these data in making decisions which relate to changes in the system to reduce the risk, or assumption of the risk.

Without these data, risk decisions tend to become intuitive since the alternatives to risk assumption are never developed as options. As a result, safety efforts are frequently focused either on solving the wrong problem, or on developing the wrong solutions for the right problems, or worse still, there may not be an understanding that a problem exists. All of these factors combine to result in continuing high accident frequencies.

The significant thought under this conceptual approach is that organized, disciplined efforts are devoted to the discovery, evaluation and removal of the critical hazards by redesign, or an alternative method, either before these hazards are built into the system, or before they are discovered by high accident frequencies. This is the foundation of the action-oriented approach of "First Time Safe" as differentiated from the posture of reacting to accidents which have occurred.

I consider that there is an urgency for an across-the-board adoption of a "First Time Safe" concept since it is with the systems of the future that we must place our primary emphasis. After all, the present transportation systems have been essentially a product of evolution from our original systems. As a part of this evolution, the safety problems, the hazards and the risks associated with the use of our early systems have also developed into the problems we have today. In aviation particularly, speeds have increased, the energies involved are greater, the systems, both airborne and ground based have become infinitely more complex, and the overall accident frequency problem continues to elude a satisfactory resolution. Since history is usually repetitive, it is likely that the transportation systems of the future will prove to be an extension of today's systems. There is no doubt that there will be tremendous advances in the state-of-the-art, especially in the area of controls, because of our rapidly expanding ability to sense and process enormous amounts of data in a short time. Still, the evolutionary process of growth and development we see today will be likely to continue into the future, probably at an accelerated rate.

It is also apparent that we must find a way of making a significant breakthrough in the reduction of aircraft accidents we have been experiencing. For example, the Safety Board is particularly concerned with the problem of approach and landing accidents and with the midair collision problem.

Also high on our list of problem areas to be solved are: (1) The need for devices and methods to prevent aircraft fatalities from post-crash fires; (2) the need for procedures and methods to improve "on ground" emergency escape from high, wide-bodied jets; (3) the establishment of aircraft performance requirements and certification standards compatible with human performance limitations and the elimination of design-induced pilot error; and (4) in general aviation particularly, the improvement of aircraft crashworthiness. Unless we are successful in solving these problems, and many others of which you are well aware, they will become part of the future system, probably in addition to an entirely new set of problems.

It is obvious that the requirements for aircraft accident investigation will continue to exist as part of our learning process. Nonetheless, the system safety methods applied to the discovery of hazards and to the assessment of risks, -- together with the employment of the risk management technique for utilizing these data, -- would appear to offer an effective way of improving the results of current aircraft accident investigation.

But whatever new investigative techniques evolve you gentlemen should never forget that you have already contributed vitally to the outstanding safety record of world air transportation. I am confident that you will sustain that record in the future.

KEYNOTE ADDRESS

GEORGE S. MOORE

Associate Administrator for Operations
Federal Aviation Administration

I welcome this opportunity to participate in your third annual international seminar and look forward to renewing some old friendships and acquiring new ones.

The contributions made by the Society of Air Safety Investigators to the advancement of air safety, individually and collectively, have earned increasing recognition in the aviation community since your organization was formed in 1964. The growth of this Society in recent years to a current enrollment of some 900 members attests to your deep concern with air safety. Your goal is recognized not only in this country but also by the international aviation community as well. You are to be complimented on the fact that there are 30 foreign nations represented on your membership rolls. Several of these countries, I am told, are represented by 10 members or more each.

The title of <u>Air Safety Investigator</u> is more than just a label. It connotes a motive beyond the investigative aspects of your duties. It indicates an intention to prevent accidents from happening as well as to investigate those that do happen. It describes the air safety investigator not as a spectator sitting on the sidelines waiting to go into action only after an accident has occurred, but rather as an active participant in the day-to-day challenge to prevent the accident from occurring at all.

In commenting on your program theme, "The Future for Aircraft Accident Investigators," Governor Reed has stated that we were in the unique business of dedicating our lives to the prevention of accidents which, he said, was really an attempt to put ourselves out of business. He added that, from a practical standpoint, there is a future for our investigators but trusts that "the frequency of their call to duty will be on the decrease, hopefully because of an increase in the effectiveness in both investigative and preventive activities."

This is not merely a goal; it is an absolute necessity if aviation is to continue to flourish in this country. This imperative to decrease accidents is predicated on the forecasted growth in aviation. The challenge is this: if the accident rate merely stays constant with little or no improvement, then any increase in aviation activity will obviously result in an increase in the number of accidents. This is totally unacceptable. Neither we nor the aviation community nor the general public can tolerate such a situation. We must continue to bring down the accident rate and do so substantially.

The aviation growth that we in the FAA foresee is enormous. According to our current ten-year forecast, we can anticipate a doubling and even a tripling in certain areas of flight activity by 1982. For example, aircraft operations handled by towers are predicted to soar from about 56 million annually at present to approximately 130 million a decade from now.

The general aviation aircraft inventory is expected to increase from its present level of over 130,000 aircraft to more than 200,000 by 1982. Of particular interest, also, is the predicted increase in the number of general aviation operators flying under IFR. The number of such aircraft handled by ATC enroute facilities will rise from 4.8 million to over 18 million during the next 10 years. So it should be obvious to all of us that we can take little comfort in a continuing low accident rate that does not show dramatic improvement.

The FAA has, in my view, embarked on a bold program to meet that challenge. It is a program designed to upgrade the man, his vehicle, and the system in which he operates. Because the man -- the pilot -- is so fundamental to any improvement in aviation safety, FAA has undertaken a comprehensive revision to Part 61 requirements which govern pilot certification and proficiency. The revised rules will provide a more up-to-date approach to proficiency and training requirements for private and commercial pilots.

The new rules will be designed around a total operational training concept in which the student will be expected to demonstrate proficiency in the various areas of pilot operation instead of specific procedures and maneuvers as now required. For example, the student would receive flight instruction in airport and air traffic operations, in performing critical slow speed maneuvers, engage in more night flying, in the use of instruments to conduct simulated emergency climbs and descents, in following radar and DF headings, obtain solo experience at tower equipped airports and engage in more extended cross country flying.

Every pilot, except airline and certain commercial pilots, would be required to undergo a proficiency flight review by a certificated flight instructor each 24 months. Because of the increased responsibilities to be placed on the instructor under the revised rules, flight instructor standards also will be raised, so that instructors would be required to hold a commercial license with an instrument rating along with aircraft category and class ratings.

Other Part 61 requirements will include annual checks for instrument-rated pilots whose recency of experience has lapsed, instructor flight checks before acting as pilot-in-command of a complex airplane, and mandatory flight instruction in specified operations before taking a test for a multi-engine rating.

Part 141 rules which apply to pilot schools also will be revised to provide more realistic requirements and standards for pilot school certificates.

The revised Part 141 rules will align the concept of the certificated pilot school program with the proposed revision of Part 61. As in the case of Part 61, the rules governing pilot school certification have become somewhat unwieldy and inflexible to administer. We plan to take a completely fresh approach in our revision of Part 141. We will base our certification of pilot schools primarily on the school's ability to show satisfactory and effective pilot training rather than solely on the basis of the facilities and equipment it presents for inspection at the time it applies for a certificate. Evaluation of the school's training record will be emphasized. Accordingly, our proposal will provide for full school certification only in the case of schools that have a demonstrated pilot training record. Other schools would be provisionally certificated. In addition, there would be provision for certification of certain school graduates without further FAA tests. Each school would be required to develop its own lesson plans in accordance with general curricular materials contained in the rule. These plans would provide maximum flexibility in training methods and they would have to be approved by FAA. Schools would be required to maintain both quantitative and qualitative standards. They would further be evaluated on the basis of sampling both students in training and those graduated.

Improved aircraft design, in airframes, power plants, and airborne equipment, is also part of FAA's long-range efforts to meet the challenge ahead.

Additional efforts will center on development of better criteria for in-flight fire protection and lightning protection.

While considerable improvements have been made in crash survivability and fire hazards in recent years, additional emphasis will be placed on crash resistant fuselage structures and fuel tanks, for both general aviation and transport aircraft. Work is planned on achieving improved post-crash evacuation. Also planned is development of test standards and methods for reducing interior cabin fire hazards and fuel tank inerting systems for preventing fuel tank explosions.

For general aviation aircraft, we want to see shoulder harnesses installed to the maximum practicable extent and plan to issue a formal proposal to this effect in the near future. This will apply both to new designs and to in-service planes if practicable. We have been devoting a considerable amount of work on impact protection covering basic research, accident analysis and hardware design studies. In addition to our rule-making program, we plan to issue a crashworthiness design handbook in the very near future. If we can provide the occupant with improved impact survivability and suppress the post-crash fire, it will be a monumental step in further advancing aviation safety.

We have also undertaken a materials research and regulatory project to reduce the level of smoke being emitted from burning cabin furnishings in the event of a cabin fire. We propose to set smoke emission limits for the materials installed. An advance proposal has already been issued on this subject, with encouraging response from the public. A formal notice is now under preparation.

In addition to upgrading pilot skills and aircraft design characteristics, we also are going to continue to upgrade the system in which the pilot flies. FAA's National Aviation System Plan calls for the expenditure of over $20 billion during the next 10 years to provide for operations, facilities and equipment, engineering and development, and airport development and planning.

At the heart of FAA's improvement of the airspace system is the completion of the semi-automation of en route air traffic control. In addition to providing more efficient and safer use of the airspace, automation will reduce pilot-controller voice communications and thereby reduce cockpit workload. As a consequence, the pilot will be able to devote more time and attention to piloting his aircraft. The alphanumeric capability in the en route and terminal area, with added-on conflict prediction, will be a tremendous safety achievement.

Modernization of the Flight Service Station complex will result in a more responsive system for aiding pilots, not only in planning flights but also in providing better service to them while in flight.

Improvements and updating of our radar equipment is well underway. This prime tool in controlling traffic will become a more reliable and accurate tool, both in the en route and terminal areas.

The airport system itself will have a number of improvements. Thanks to the Airport/Airway Development Act, the nation's network of airports will get a substantial face-lifting, providing more airports, more runways, longer runways, and improved taxi strips and apron areas. Many additional control towers will be added to the system. The number of conventional instrument landing systems will be greatly increased. The microwave ILS is next on the horizon. The microwave ILS, which FAA is now looking into, is far less susceptible to interference, problems of siting, and approach path limitations than the conventional ILS.

Work is also being done on developing more effective ground based crash fire-fighting agents and techniques, better procedures and equipment for removal of snow, and on solving bird impact hazards.

There are also plans to improve runway friction characteristics and for developing methods to predict airplane landing performance on slippery runways.

The sum total of all this is a heightened awareness that those who are responsible for safety in aviation must be in the forefront to enhance that safety. That forefront is not just tomorrow but years beyond tomorrow. The Federal Aviation Administration is devoting a considerable amount of its resources toward meeting the future challenges that tomorrow's aviation will pose. We know that in the ceaseless quest for improving aviation safety we will have with us the dedicated efforts of organizations such as the Society of Air Safety Investigators.

Thank you very much. My hat is off to all of you.

THE FUTURE FOR AIRCRAFT ACCIDENT INVESTIGATORS

CAPTAIN JOHN R. McDONALD

Senior Accident Investigator
ALPA Region III

The future for the aircraft accident investigator is one that he may look on with some degree of horror. The size of the future aircraft will present him with problems that alone will make his job far different from what he has experienced in the past. Then too, the number of aircraft, which is one criterion that will lead to additional accidents, will also change the patterns that he has come to expect.

Aircraft of the past have presented enough problems, but in matters of size, the stretched version of the DC-8 or the Boeing 707 is about as big an aircraft that up to this time has been involved in an accident which required intensive investigation. These aircraft have all-up gross weights of about 340,000 pounds and have seating capacities in the neighborhood of 175-200 passengers, depending on the seating configuration used. Even from aircraft this size we have been confronted with problems that we have found to be almost insurmountable. We have managed to accomplish all of the objectives required of the aircraft accident investigator, but in terms of manpower and money we have reached the breaking point on more than one occasion. If we have these problems today, let's stop and think of what we may have to face in the future.

In matters of weight and capacity, the airplanes of the future will be some two to three times larger than those we presently are working with. This aspect of any accident should be enough to give the accident investigator cause to stop and think of the future of his profession. the size of the aircraft will no longer permit the rebuilding or "mock up" of the aircraft from the wreckage. Where we once were able to take the time and spend the effort to make such "mock ups", we are no longer going to be able to so do. Where could we find a hangar or other space to use, and the equipment to support such an effort? The cost of such an undertaking would rule it out even before it is started. Some mock ups of small related areas may be possible, but I believe that the size of the aircraft will, in itself, cause such destruction that we will have little left with which to make a mock up.

The clamor of the public has forced many changes in the paths of airways and the expected clamor against future aircraft will require additional changes. The use of airways that cross over largely undeveloped areas for most of their distance, and others that cross over large bodies of water, will lead to many problems that have only been brushed over in recent years. Of late, the National Transportation Safety Board's Bureau of Aviation Safety has gained considerable experience in the location and salvage of underwater wreckage, but to my recollection all of these have been very close to large land masses.

The ability of the future airplane to cover vast areas nonstop will increase the number of flights over areas that are farther from land than we have experienced in the past. We should expect an increased exposure to more accidents of the type experienced by The Flying Tiger Line Connie over the Pacific between Guam and the Philippines on March 15, 1962, from which we have never recovered enough wreckage to be able to ascertain the reason for the aircraft's disappearance. In a similiar manner we lost a B-727 in Lake Michigan and while we were able to recover 80% of the wreckage, we never were able to come up with the Cockpit Voice Recorder or the Flight Data Recorder, the two essential bits of equipment that we needed to indicate a reason for this accident.

The Congress of the United States placed the responsibility for investigating all aircraft accidents on the National Transportation Safety Board. The Congress, in typical fashion, then failed to supply the NTSB with the funds necessary to do the job that it is supposed to do. In the case of the Lake Michigan and Santa Monica Bay B-727 accidents, the NTSB was placed in the position of asking the parties to the investigation to contribute monies to the continuation of the underwater search and recovery program. Other requests to the Budget Committee to expand or develop sections of the Board's Offices have been denied.

The increased activity in the field of liability in aircraft accidents presents another problem to the accident investigator. A few years ago this aspect of an investigation was of little concern to the investigator. Today it has to be of concern due to the tremendous increase in the number of cases filed and the size of the judgments granted. While the Regulations of the NTSB, in most cases, deny the use of its investigators or its reports in any court, it is well known that many portions of the Board's reports are used frequently in civil court actions.

With all these things working against the accident investigator, it is obvious that something must be done to continue and/or improve the quality of the investigations required of the Board.

The use of recording devices must be improved and expanded. Years ago, when the suggestion was made that an airborne recording device be required, ALPA was one of the original suggestors and supporters. While much of the aviation community rebelled at the idea due to the cost of the project, ALPA urged that such devices be required. This backing of these devices was made under the impression that the devices would be used solely for the purpose that had been suggested, namely, accident investigation. For some time the devices were used for just that purpose and they supplied a great deal of useful information. They also pointed out the areas in which the devices were inaccurate and some improvement in the capabilities of the FDR was recommended. As time passed, some individuals responsible for the use of the FDR came to the conclusion that this unit could be used for other purposes. By adding some parameters it could be used as a maintenance recorder and provide information necessary for the aircraft's maintenance program. This idea has returned great dividends to the companies that use it. Without changing the unit at all, it could be used as a pilot performance monitor. It could be used as a device to determine the guilt or innocence of an individual pilot. It could be used to support accusations made from other sources. All of these uses could be of value, even with the knowledge of the inaccuracies of the units in use. The files of the NTSB are filled with the readouts of units taken from aircraft involved in accidents. In many cases the record, when read out, indicates activities that are totally inconsistent with the observed performance of the aircraft. Recently the industry implemented expanded Flight Data Recorders. The Air Line Pilots Association has sought this expansion for many years, but we supported this action in a modified form. It is our position that the use of such recording devices should be limited to accident investigation purposes only.

With this limitation on the use of these devices, and we will never be able to obtain complete use of them without such a limitation, the extent of their use is almost unlimited. Without such a limitation, the complete cooperation of all areas of the aviation community, necessary to make a success of the operation, will never be achieved. We must take steps to assure that the information contained in the FDR is available only to those experts qualified to read out the record and that the interpretations are then kept from those who would use the information for their own purposes. The U.S. pilot flying in foreign airspace must have this protection made available to him as he would have in the U.S.

The accuracy of the units must be improved and this must be done prior to the required installation of the new expanded units. It will do little to improve units after the present units have been installed. The units themselves must be made more crashworthy. They must be ejectable and have some sort of device attached to them that will permit them to be located in any type of terrain and under considerable depths of water. In the latter case they should also have the capability of floating for some extended period of time.

The number of parameters must be expanded to provide the accident investigator with the facts necessary to establish the basis for his investigation. No longer will he have the luxury of time and money to examine the entire wreckage in order to find the point at which he must focus his attention. Some consideration must be given to recording the parameters in a manner that is compatible with computerization. Time is going to be of the greatest essence in future accidents. We cannot wait for many months to obtain the reasons for the accident confronting us. Telemetering of the information may be of help in more than one way. Information so telemetered to ground stations has been used in maintenance activities in the past. In such use it has pin-pointed possible failures long before any other method of examination would have pointed them out and certainly long before the crew could make note of them. Thus, this information could be telemetered from an airplane flying over India to its home station in the U.S. via the use of satellite relay and be used in both the operator's maintenance program and his accident prevention program.

The ability of the NTSB to read out FDR's must be supported so that such media can be reported on within a reasonable time after the accident. The accuracy of the units has been mentioned before and again the capability to determine corrective factors to apply to the information contained in the recorder must also be improved. The ability of the investigator to correlate the information gained from the FDR must extend all the way from the Readout Expert to the Field Investigator in Charge of the investigation.

In much the same manner, the capabilities of the Cockpit Voice Recorder must be improved. Recently we have changed the location of some of the Cockpit Area Microphones in an effort to obtain greater fidelity in the voice recording. While this may supply some help, a tape removed from a B-737 accident two years ago is completely unreadable in the area mike channel. The ability to filter out unwanted moise must be improved. It will, of course, be better to keep the noise from being recorded in the first place, since in any filter attempt we may have removed the one sound that will give us the clue that we are looking for. We must be better able to interpret noises presently identified as "unidentified or unknown" or simply as "click", etc. A year ago last spring the Board went to a policy in which a pilot member of the airline involved, who was qualified on the airplane type and knew the crew, would be a member of the group reading out the CVR tape. This will provide some additional input in this area and will serve to identify many of the sounds that we have not been able to identify in the past. Another method that we in ALPA have found to be of considerable help is to refly the trip in the same type of airplane and record the entire flight. As each action is taken by the pilot, the sound is identified by an observer. In this manner, sounds that were not capable of identification in the North Central Airlines Convair 580 accident at O'Hare International Airport were positively identified by ALPA investigators. The Board's CVR readout experts must be given the equipment and time necessary to identify all the sounds recorded.

The ability of the Board to perform its own examination of wreckage must be improved. At present the Board is very limited in its ability to examine many areas of importance. As an example, the ability to microphoto fracture surfaces must be provided to the Board. To require that the Board go to the manufacturer of a failed part to determine the reason for its failure is inconceivable. It involves pressures and possibilities that cannot be condoned.

The investigator must be removed from any possible political or industrial pressures. He must be able to make his own determination of the facts as they are, and not as they may affect the industry or any individual.

The Public Hearing must be removed from the arena of public TV and news media and placed in an atmosphere conducive to the examination of technical facts. The Association has made suggestions in this area to the Board.

In summation, the future of the aircraft accident investigator will lie more in the office and the laboratory than in the mud of the field at the accident site. He must become more of an engineer himself and be relieved of the necessity to rely on others. He must be better trained than he has been in the past. He must have a complete knowledge of the aircraft he is working with. It may be that it would be well worth the time and money to have him qualified on the equipment, so that he has a positive knowledge of the manner in which the aircraft is operated. He must become an expert, or at least a specialist.

I have not mentioned the field of general aviation accidents since I am not involved with them and the number of such accidents alone makes them a subject by themselves. To those who have to investigate the vast and increasing number of such accidents, I can only say "Good Luck".

Naval Air Test Center
Patuxent River, Maryland

Navy Underwater Crash Locator Program: Report of Search Operations for F-14A Ship #10

by

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Technical Support Division

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NAVY UNDERWATER CRASH LOCATOR PROGRAM: REPORT OF SEARCH OPERATIONS FOR F-14A SHIP #10

by

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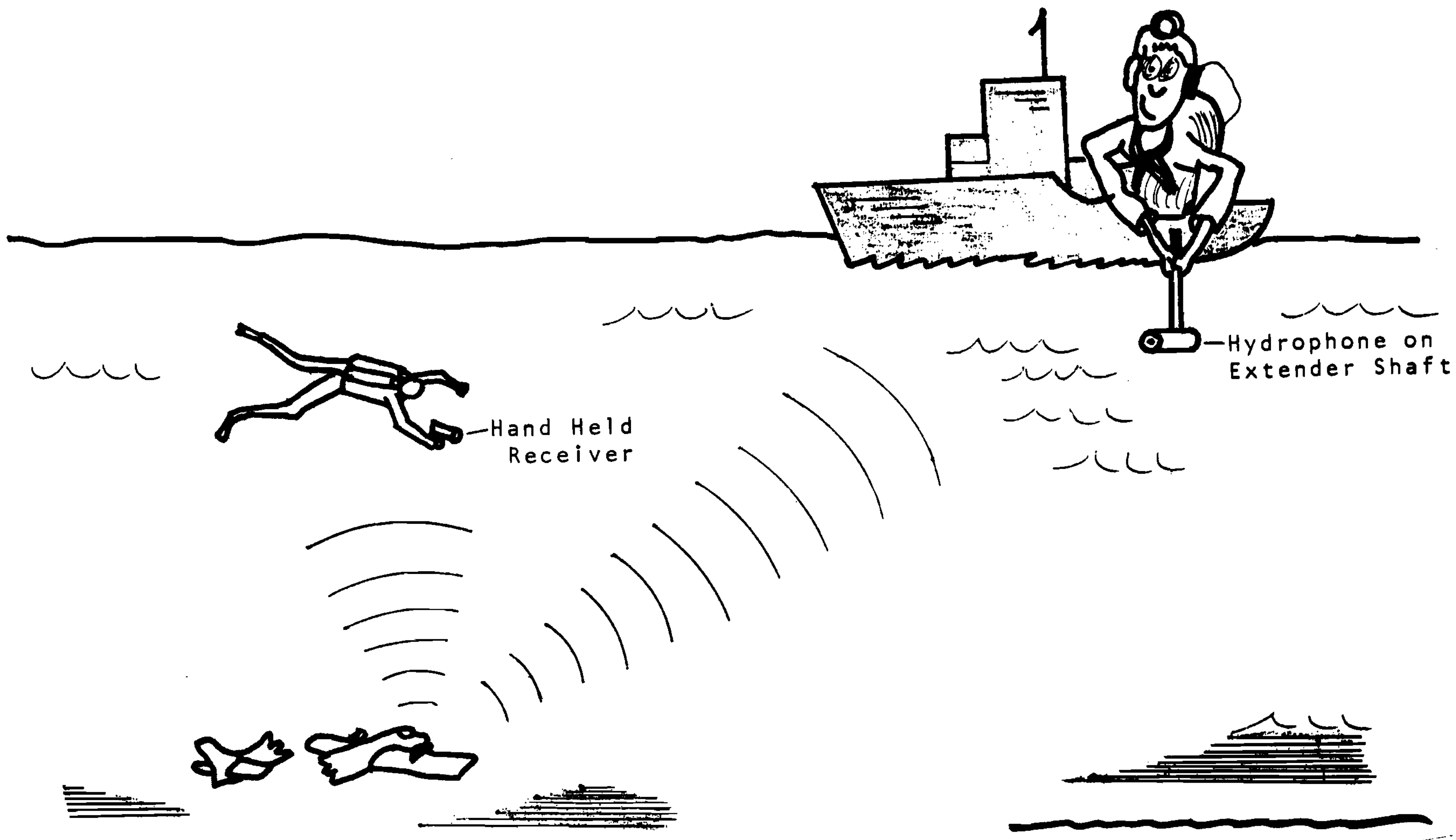
ABSTRACT:

The Naval Air Test Center is presently engaged in a project to install underwater crash locators in all Navy test aircraft flying over coastal waters. The scope of this project is presented along with operational experience gained while searching for the wreckage of F-14A Ship #10.

Fig. 1 PINGER, MOUNTING BRACKET, AND TEST SET


Hydrophone on Extender Shaft
Hand Held Receiver

Introduction:

Over the years numerous Navy aircraft have crashed in shallow coastal waters, some of which are never located nor the cause of their crash determined. In many cases the funds expended searching for the wreckage is very high. Costs as high as $300,000 have been incurred in the fruitless search for one aircraft.

As early as 1966, the Naval Air Systems Command (NASC) started testing acoustic beacons (pingers) for possible use as aircraft underwater crash locators.

The pinger is a small battery power device which radiates an acoustic signal upon activation by a water sensitive switch (see figure 1). Search operations are conducted utilizing a portable receiver with a directional hydrophone (see figure 2). The receiver system can be operated from small boats or by SCUBA divers. During the

Fig. 2 PORTABLE RECEIVING KIT

same period of time (1966-68), the Federal Aviation Agency (FAA) and the National Aeronautics and Space Administration (NASA) also conducted tests to determine the suitability of pingers to locate objects underwater. The results of these tests have been documented (see references 1 and 2).

On 23 February 1972, the Naval Air Test Center (NATC) was directed by NASC to implement a project to install pingers in all test aircraft flying over shallow coastal waters. Just five months later the pinger system received its first operational test following the crash of an F-14A at NATC.

PART I

NATC Pinger Project:

The Naval Air Test Center will provide pingers, receivers, and test units to all designated NASC field activities with test aircraft flying over coastal waters. The equipment will be supplied and administered as an item of the NAVAIR Instrumentation Pool which is operated by the NATC Technical Support Division. This Pool was organized for the loan, re-utilization, centralization of special airborne instrumentation within the NASC field activities and Navy aircraft contractors.

The activities and aircraft to receive pingers will be defined by the NASC Test and Evaluation (T&E) Coordinator. The T&E Coordinator, located at Patuxent River, Maryland, will also provide coordination for the implementation of the program at the Navy field activities. Table 1. is the initial list of activities and numbers of aircraft to receive pingers.

In addition to the Navy facilities, pingers will also be installed in test aircraft which are on temporary loan to contractors. Table 2. is the initial list of these contractor facilities. Approximately 58 aircraft at these facilities will receive pingers.

TABLE 1. NAVY ACTIVITIES AND NUMBER OF AIRCRAFT TO RECEIVE PINGERS

Activity	Number of Aircraft
Naval Air Test Center Patuxent River, Maryland	98
Naval Missile Center Point Mugu, California	31
Pacific Missile Range Point Mugu & Hawaii	27
Naval Air Facility Warminister, Penn.	14
Naval Air Test Facility Lakehurst, N. J.	12
Naval Ship R&D Lab Panama City, Florida	3
Naval Air Station Brunswick, Maine	2
	187

TABLE 2. CONTRACTOR FACILITIES

Lockheed Aircraft, Burbank, California
Hughes Aircraft, Culver City, California
McDonnell Douglas Corporation, Long Beach, Calif.
Rohr Corporation, San Diego, California
Sikorsky Aircraft Corporation, Stratford, Conn.
Grumman Aerospace Corporation, Bethpage, New York
Westinghouse Electric Corporation, Baltimore, Md.

The Naval Air Test Center has also been directed to provide; mounting instructions for the pingers in each type of aircraft, operational search plans, and technical control of the project.

Project Status:

A contract has been awarded by NATC to the DuKane Corporation, St Charles, Illinois, for delivery of 315 model N15F210B pingers at $162.00 each. The same model has been procured by the FAA for use in commercial airliners. The performance specifications of the units are shown in Table 3.

TABLE 3. PINGER SPECIFICATIONS

Operating Frequency	37.5 ± 1.0 KHz
Pulse Rate	1 Pulse/Second
Search Range	2000 - 4000 yards
Operating Depth (Pinger)	20,000 feet
Operating Depth (Receiver)	200 feet
Operating Life (Battery)	30 Days
Shelf Life (Battery)	1 Year
Size	1-1/4" Diameter x 3-7/8" long
Weight	9 ounces

The DuKane Corporation has also been contracted to furnish its model N30A5 receiver kit and model 42A12 test set (see figure 1 & 2). The receiver is convertible for use from the side of a boat (see figure 3), or by a SCUBA diver (see figure 4). The test set is used for periodically checking the pingers after installation in the aircraft. Cost of the receiver kit is $2000.00.

The best location of the pinger for each type of aircraft is presently under study at NATC. Their are 34 types of test aircraft (A-7, F-4, etc), involving 67 models (A-7A, A-7E, F-4B, F-4J, etc), which have been designated to receive pingers. Determining factors in the location are temperature, crash survivability, ease of servicing, protection from moisture, and probability of flooding after crash. Pingers have presently been installed in 16 different types of aircraft at NATC. In addition all F-14A and S-3A test aircraft have pingers on-board.

Quality control of the pingers will be performed by the airborne instrumentation standards and calibration laboratories at NATC. All pinger units will receive an operational check. Random units will be tested for vibration, shock, temperature, and battery life. A file will be maintained of all units which are defective or fail in service. This data will be used to build a history of performance and lifespan. This history will be used to determine future schedules for service checks and battery replacement. Present plans call for changing batteries once per year. Functional checks of the pinger will be required at the time of the aircraft calendar check. The calendar check varies by aircraft type from once every 13 weeks to once every 34 weeks.

Their is no plan at this time to perform extensive antenna pattern or search tests in the water. These type tests have been performed in the past and documented (see reference 1). It is planned, however, to perform limited search tests in the water to gain practical operational experience.

Fig. 3 RECEIVER AND HYDROPHONE CONFIGURED FOR SEARCH FROM SMALL BOATS

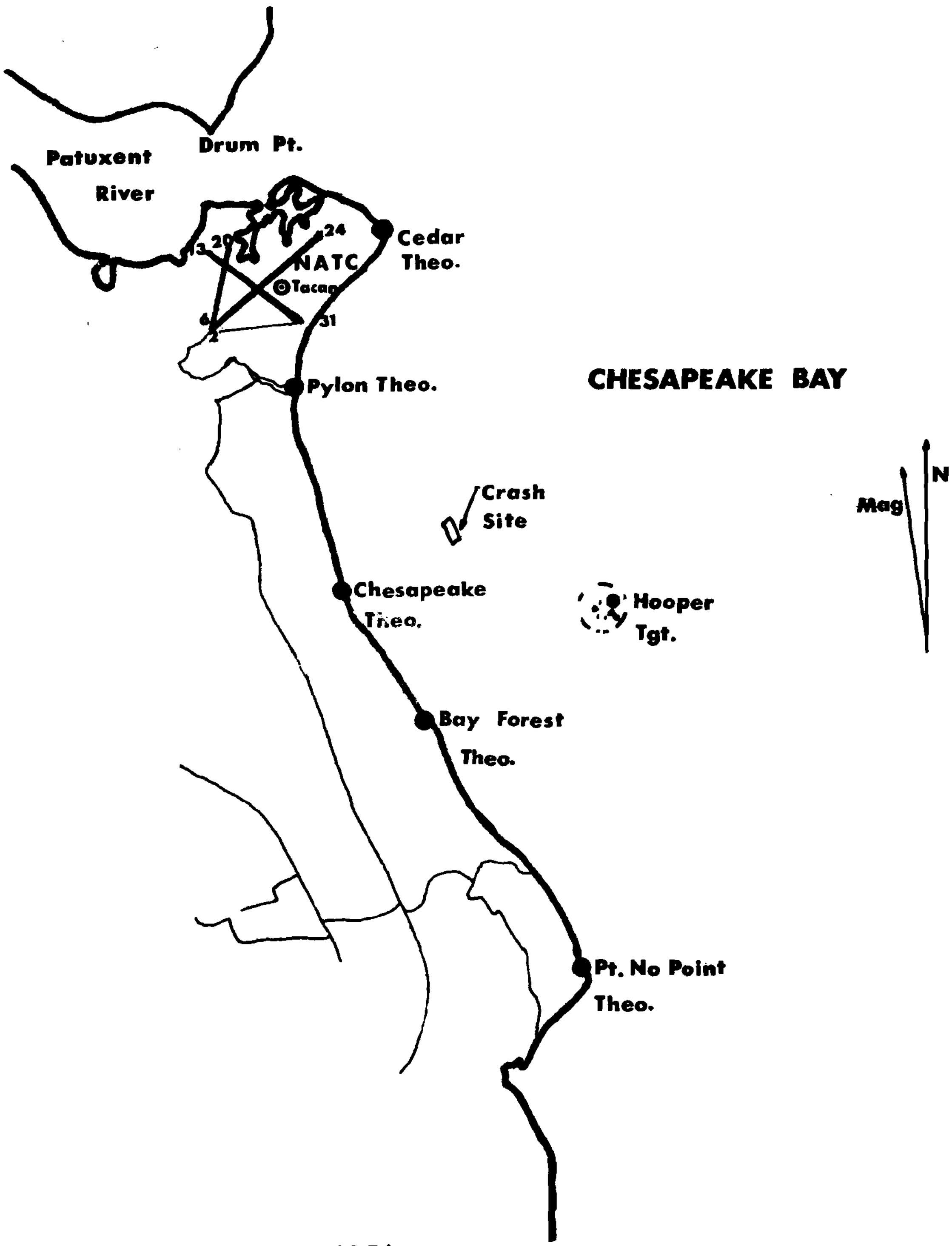


Fig. 5 MAP OF THE NATC AREA INDICATING THE LOCATION OF WRECKAGE

Fig. 4 RECEIVER AND HYDROPHONE CONFIGURED FOR SCUBA DIVERS

PART II

<u>Search for the Wreckage of the F-14</u>:

At approximately 2:00 pm on 30 June 1972, F-14A ship #10 crashed into the Chesapeake Bay at a point 4-1/2 miles southeast of the Naval Air Test Center (see figure 5). This aircraft carried a pinger which had been installed by the Grumman Aircraft Corporation.

Pinger receiving equipment, on order by NATC had not been delivered as of the date of this accident. Mr. Edgar Williams, the pinger project engineer at NATC, had borrowed one old unit (1966) for laboratory testing. This unit was available at the time of the crash, however, Mr. Williams was traveling on another project. The search was conducted therefore by his supervisors, Mr. Paul Davis (the author) and Mr. Terry Collom, who were familiar with the pinger project. It is interesting to note, however, that prior to this search neither Mr. Davis or Mr. Collom had assembled or operated the receiver unit. The following is a narrative of the search.

---at approximately 3:00 pm on 30 June 1972, I received word that the F-14 may have crashed. I was aware that F-14A ship #10 was carrying a pinger. Mr. Collom was requested to check the status of our receiver unit while I was confirming the crash and its location. The crash of the F-14 into the Bay was confirmed, and the receiver unit satisfactorily checked out.

Mr. Collom and I proceeded to the Operations headquarters to notify them that we might assist in locating the wreckage. We were sent directly to the Chesapeake Bay boathouse to be picked up by a Navy crash boat. We boarded the crash boat at approximately 4:30 pm and proceeded directly to the crash area (see figure 5). While traveling to the search area I received a radio call from shore. The call forwarded the exact operating frequency of the F-14 pinger which was 38.7 KHz. The approximate search area was known because of eyewitnesses and floating debris and appeared to cover four square miles.

Upon arrival in the search area, we first tested our receiver with a new pinger which was brought along for this purpose. After this successful check, the hydrophone was dipped into the water. Immediately a signal from the F-14 pinger was received. The direction of the wreckage was determined by rotating the hydrophone until maximum audio signal was obtained. Tracking the signal was conducted by stopping the boat every 300 - 500 yards and submerging the hydrophone in the water. It was not possible to hold the unit vertically in the water when the boat was underway.

The signal was followed for approximately 1/2 mile. At this point the signal appeared to be weaker, and it was questioned if the hydrophone was indicating the true bearing.

As the boat drifted we lost the signal entirely. Slight background noise was audible. The noise was directional and appeared to be originating from other boats. The question of depth finder interference was also mentioned, but this is not a problem. As the boat continued to drift in a circle, the signal was reacquired. This time we easily followed the signal for approximately 1 to 1-1/4 miles. At this point the bearing of the signal reversed by 180° indicating that we had passed over the wreckage. At this moment the master diver arrived on the scene, and we transferred to his boat.

As we were now close to the wreckage, the receiver was transferred to a Navy diver. Utilizing the directional hydrophone the diver swam for approximately 100 yards, where he contacted the first piece of wreckage at 6:05 pm. This

Fig. 6 F-14A PINGER LOCATION, RIGHT REAR SPONSON COMPARTMENT JUST FORWARD OF THE HORIZONTAL TAIL

piece was a six foot section of the right rear sponson where the pinger was installed (see figure 6). The visibility in the water was less than one foot, and the diver actually followed the signal until he bumped into the wreckage. The poor visibility is attributed to the normal muddy bottom of the Bay, the recent passing of Hurricane Agnes, and the overcast sky conditions. The diver who had no previous checkout on this equipment appeared very enthusiastic and commented, "it was just like following a road map." One more dive was made locating several more pieces of wreckage before securing for the night.

The wreckage was found in 32 feet of water, approximately 1-1/2 to 2 miles from the initial search point, and 1/2 mile east of buoys dropped by other crash boats. The

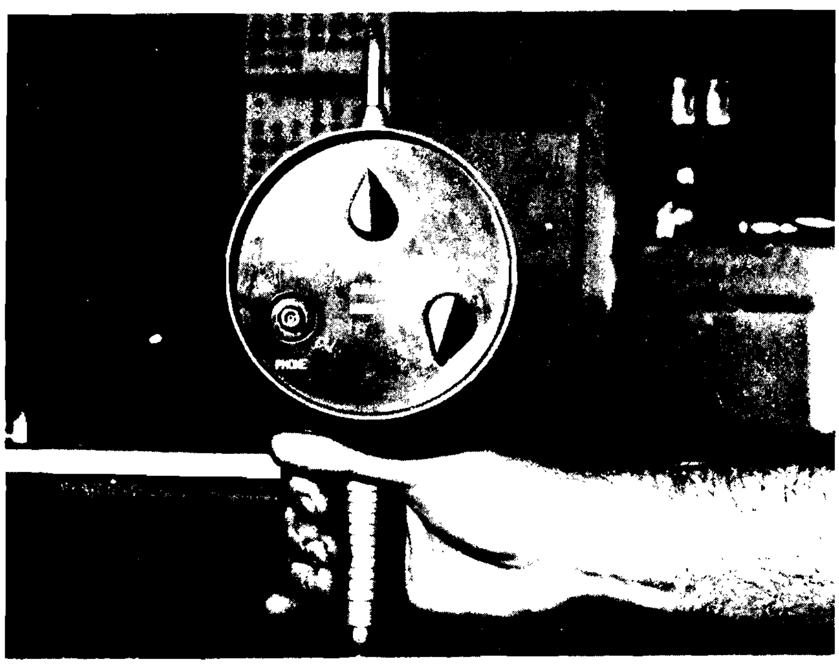


Fig. 7 HAND HELD RECEIVER, SHOWING CONTROL KNOBS

is undoubtedly the most suitable from the standpoint of availability, portability, performance, accuracy, and ease of installation in ships of opportunity. Its accuracy is excellent, and its repeatability exceeds any other system available today. It is basically unaffected by weather thereby permitting excellent search continuity.

Search and target acquisition in the distant, deep ocean areas rests on either the use of satellity navigation systems or an underwater bottom reference technique. It may well be that both systems would have to be used; since in long-range problems, navigational accuracy can best be called navigational positioning with proven plotting accuracies no finer than one to two nautical miles.

Therefore, in the distant deep ocean areas, the search task requirement for navigation becomes the most critical in terms of availability, performance and cost. The Project Manager may have to resort to a sea-floor beacon or transponder navigation system utilizing hull-mounted receivers in order to conduct a "relative position" search within the primary area of interest. Such a system is installed in and utilized routinely by ALCOA SEAPROBE for deep water positioning, tracking, target marking, and small area, deep water search operations. For ships of opportunity, however, this mode of search navigation is a long-lead time, high cost and complex system requiring either time-consuming manual plotting and interpretations, or a computer installation with its concomitant cost and need for specialized operator expertise.

The availability of surface support platforms is another important consideration in the conduct of an underwater search. Ship characteristics that must be considered include:

Overall Length
Maneuverability
Sea-Keeping
Course/Track-Keeping
Search Speeds
Deck Space
Lifting Equipment
Berthing Accommodations
Single vs. Dual Engines

Navigation Equipment Installed

Age/Condition

Power Available for Search Sensors

Communications Equipment

Covered Charting Space

Size of Object to be Recovered

Additional Navigation System Requirements

There is one other system which has not yet been addressed, and it is far and away the most important. This is the people who will assist in, or actually perform the work. As in every walk of life, whether it be teaching or going to sea; people are our most important product. Selection is normally based on people who:

Know their profession intimately.

Have a working knowledge of the basic task.

Respect each other's abilities.

Are willing to help each other and are not afraid of hard work.

While these may sound like rather trite statements; there is one inescapable conclusion about people who work in the water. It is that they are there because they want to be. And, that's a big initial asset.

SEARCH PHASE

Once the survey, analysis, and equipment selection phase has been completed; the primary steps in the Search Phase can begin; i.e., mobilization, installation and checkout. This period is an important part of the search, and should be spent in insuring that everything is in readiness for the at-sea task, including all gear properly secured, and all hands completely briefed on the Search Manager's intentions.

While on-scene weather and actual bottom conditions may dictate alterations in the initial intentions; search area grids will have been selected, charts and overlays drawn, and search lane widths verified as to spacing and overlap. Task records and log sheets required will have stipulated, as will search hours, contact logging, communications, etc.

In order to better illustrate these phases, two actual operations will be briefly described. The first took place in Great Salt Lake in 1971, following an aircraft crash and unsuccessful two-week search by divers using hand-held sonar. Telephone contact and travel to the scene by the Search Manager revealed the following basic information.

The aircraft had been under radar track, but had departed this envelope enroute to base.

Although the aircraft did not return to base immediately, no overt action was taken to contact the craft or institute a search until the "fuel exhaustion" state was reached.

The initial search was limited to aircraft/helicopter searching, since no surface craft normally operated in the concentrated brine of Great Salt Lake.

Some small surface debris was sighted along with an oil slick, well after "fuel exhaustion" by search aircraft and a buoy dropped. A Tacan fix was also taken by the search helicopter.

Subsequently, small craft were dispatched to the scene, as they became available -- unfortunately, one of the first craft out had run over the marker buoy line and cut it.

Using limited visual fixes, a diver search had been initiated, but without success.

With this information in hand, the Search Manager commenced a thorough review of all background information, including the recorded track and last known position of the aircraft. Aircraft speeds, turning radius, search crew interviews, and diver debriefing were also all "put into the hopper".

Not surprisingly, a major constraint in the survey investigation was the complete lack of a standard nautical or surveyors chart applicable to the Great Salt Lake. A painstaking search finally turned up a copy of a Mercator chart drawn some twenty-four years earlier as a training exercise by the Naval Reserve Unit in Salt Lake City! The chart was accurate in almost every detail, and was reproduced and used to plot the aircraft track, search areas previously covered, and the intended search grid.

A small craft suitable for the search was chartered and a navigation and sonar system mobilized. Shore stations for the navigational system were selected and set up, and the side-scan sonar and master navigational unit were installed in the search boat. The search commenced around the reference buoys used by the divers; as well as the primary area selected by the Search Manager, while concurrent plans were made to have the same helicopter and search pilot fly to the original Tacan bearings to plant a second datum buoy. This latter was done with the search boat immediately nearby and a precise navigational fix established at the drop point. The search then commenced in earnest with lane spacing selected to permit a ninety percent overlap of the sonar pattern. This overlap was deemed necessary due to the extremely cold brine at the lake bottom (verified by divers), and the fact that the aircraft was felt to be in small pieces due to the estimated near vertical angle and high speed with which it had impacted this shallow, but very dense water, lake.

The aircraft was located on the fifth search day approximately one mile from the datum buoy. It was verified by grapnel drag and the area marked on four corners by buoys for follow-on diver recovery.

Facts of prime significance in this effort were that even with a towed, underwater sonar the effective target range was later determined to be only 70 percent of selected range due apparently to the rough bottom character and cold brine near the bottom. (It is felt that this would have seriously derogated or even defeated a surface sonar search.)

There were no boats normally in use in Great Salt Lake requiring one to be hauled in for the search.

Although the search was conducted within close proximity to land, no current accurate, navigational charts were in existence; nor were surveyed landmarks present.

It is doubtful whether the aircraft would have been found by the initial diver search, since the difference (one mile) between buoy and actual position is considered extreme for divers with only a foot of visibility.

In the second operation, a small light aircraft was lost in the waters of Boulder Canyon, Lake Mead. The Search Manager was contacted almost immediately in this case and proceeded to the scene shortly after the crash.

The circumstances here were rather bizarre, since the canyon walls of Arizona and Nevada were only about 3,000 feet apart on either side of the water-filled canyon. Although no precise location was in hand, the canyon was narrow and small enough to permit adequate visual piloting with the placement of buoys and shore markers. Two serious problems did exist however -- the water depth was 400 feet, and although a multitude of small pleasure craft were on the lake; none was really suitable to handle cable for that depth of water. There was also no adequate diving or salvage equipment available to the search team.

A side-scanning sonar was used in the search effort, which was deployed from a National Park Service utility boat. (In order to handle the towing cable, a homemade winch was fabricated, using a pipe threading machine for turning the shaft.) Since recovery of the aircraft had been stipulated from the outset, on-scene construction of a salvage barge and lifting davit was commenced and a bell diving system ordered on standby.

The sonar search was nightmarish in that acoustic "ringing" from the near canyon walls prevented any effective sonar contact discrimination. A T/V drop to check the bottom also indicated zero visibility in the soft mud particulate suspended near the bottom from years of river deposit.

In order to prevent the sonar "crosstalk", one side of the sonar was deliberately disabled and the search sweep conducted hard against one canyon wall, while scanning towards the other. This procedure resulted in an improved sonar return with a definite contact, but with still too much reflective acoustic echo to be satisfactory. (The diving bell system was ordered in, however.) The output power of the active side of the sonar was then reduced to half; the sonar physically tilted downward approximately 10° to minimize canyon reflection, and surveys again made hard against each canyon wall, scanning outward. This procedure proved to be excellent, and clean, sharp sonar records were obtained of the aircraft. (The procedure almost lost the sonar too; since it became wedged in a fault along the near canyon wall requiring several hours to free it!)

Once the aircraft was definitized and localized, surveyors were placed on the shore line to accurately locate the position and installation of the diving bell system commenced. (During this time the barge construction had been proceeding at a fast pace and was almost ready for outfitting.)

As the divers, diving equipment and breathing gas arrived (helium oxygen), the barge was fitted out and towed to the loss site. Stability calculations had also been previously made to insure safety and the lifting davit tested. Moorings for the barge consisted of 1,000 lb. LWT anchors in the lake and re-inforcing rods (rebar), driven into the shore line.

A dry observation dive was made to check on bottom conditions. There was absolutely no visibility and about a fifteen foot layer of soft, talcum-like mud prior to hard bottom. A second "dry dive" was made with a crystal string from the sonar mounted on the bell. Using the crystal string, the barge with the bell suspended below it was maneuvered over to the aircraft contact (within an estimated ten feet).

The bell was then brought up and divers embarked. A lock-out dive (395 feet), was made with the diver able to find the aircraft almost immediately. Since it was past dark and with lengthy decompression still to follow; a line was made fast to the aircraft and the dive terminated.

In order to insure a proper lift of the aircraft, a similar aircraft had been located and was flown in to a nearby air field the following morning. All of the divers were familiarized with the plane (it was determined that the lost aircraft was upside down), and lift points selected to initially lift the plane. A sling was also fabricated for final lift from a planned depth of about 30-50 feet.

The second lock-out dive was made after a complete briefing and the initial recovery hook-up and lift went very smoothly. Lift was stopped at about 50 feet and the aircraft righted and dewatered safely; while hanging on its proper sling. It was then lifted and loaded onto a homemade float, borrowed for the occasion, and delivered safely to shore.

This task was notable in that the survey, search and recovery took twelve days from the time initial phone contact was made until all equipment and personnel were back at their base locations. This included all mobilization/demobilization and outfitting of a work barge on the scene.

RECOVERY PHASE

Underwater recovery, the normal culmination of a successful search effort, requires considerable foresight and meticulous planning. In every underwater recovery task (and no two are identical), no fixed, predetermined course of action can be applied throughout due to the many variables present when working at sea. The initial recovery concept planning can, however, be done during the investigatory phases of the search survey in order to expedite the actual follow-on work. Parameters which can be co-determined during the initial survey phase and confirmed in the search phase include:

Overall object size, weight and construction
Final distance offshore
Average weather and sea state
Base depth over the intended search site
Water temperature
Recorded current and/or tidal data
Type of bottom, i.e., mud, rock, shell, sand, etc.
Recovery equipment and personnel
Moorings and ancillary equipment

Prime and alternative recovery techniques should be selected and provided for early in the planning stages, so that once the at-sea task is initiated, the responsible manager has at his fingertips the necessary resources to smoothly coordinate the follow-on recovery.

During the search, the above criteria can be reshaped and modified as actual conditions reveal themselves to the Search Manager. Such details as local daily weather with its accompanying sea state will become well known. The depth at the search site can be precisely plotted by both fathometer profile and by sonar trace. Current data and water temperature can be measured in situ, and the type of bottom determined.

Once the target has been located, its sonar profile will many times confirm the initial estimates of its size, final lift weight, and disposition on the sea floor. With this continuous shaping and reshaping of gathered information, the earlier primary and alternative recovery plans can be finalized so that proper mooring, recovery equipment and personnel can then be selected and mobilized. While deep diving is not a normally preferred method of search, its importance increases once a target has been acquired and classification or recovery are required.

The use of divers and deep sea diving techniques is a valuable part of most recovery processes in those depths where divers can operate. Even though mechanical means, such as trawl recovery, clamshell or grab may be available; the post-recovery analysis of recovered articles is often the most important part of the entire task, thereby precluding the use of any system that might cause physical damage. In this event, the diver becomes a most valuable asset, since he can describe the condition of the article prior to lift and attach the lifting device at the strongest points in order to avoid or minimize damage during the recovery process.

Prior to any recovery involving divers, proper equipment selection is a must. A recovery platform of suitable size to accommodate the necessary recovery and diving equipment must be planned. Proper space must be allocated for debris and wreckage, so that the diving area is relatively free and safe to work in. Weather constraints on safe diving conditions must be considered and moorings laid which will insure the maximum stability, safety, and ease of operations. Decompression facilities must be provided aboard ship and medical support either furnished directly or located at the closest point on-shore within easy reach. Primary and back-up sources of breathing gas must be on hand and sufficient divers furnished, so that an efficient recovery process can proceed with maximum safety.

In many instances, the use of diver classification techniques is proscribed by the very nature of the task. As an example, when a lost aircraft is located on the sea floor at a depth requiring mixed-gas diving and subsequent decompression; it is less costly and more productive to classify or identify the aircraft by television and/or video-tape record. While this is being accomplished, the necessary recovery assets can be mobilized; thus insuring a smoother flowing, more orderly continuity of task stages. After the aircraft has been identified and photographed, recovery personnel can study the film/tape so as to be initially familiar with the task prior to ever getting wet.

In every recovery or salvage evolution, the Project Manager must carefully plan the recovery technique in concert with the personnel who will do the actual work. Maximum awareness on the part of all hands is mandatory. Complete understanding of the sequential operational steps and the complexities involved must exist between the surface support personnel and those who will do the work on the bottom. As in the case of any ocean engineering problem, primary and alternative recovery techniques must be selected and the proper equipment provided without complicating the task or burdening the recovery unit. Using a deliberate, planned, and well-rehearsed method of recovery is the best insurance that a successful task will result.

JERRY A. SHROUT

AVEMCO Inc.

In the next ten minutes or so I will attempt to explain to you what an insurance adjuster is, what he does and where the adjuster fits into aviation safety now and in the future. This is rather a tall order since I have been an aviation insurance adjuster for over ten years and am still in doubt as to where the job starts and ends.

In the first place, in my opinion, there are less than 100 good aviation adjusters in the United States today. To be considered good in this rather small and peculiar profession requires an unusual man since he must posses many diverse talents and abilities.

A good aviation adjuster is 50% mechanic, 50% lawyer, 50% diplomat, 50% crash investigator, 50% insurance expert and if you listened to some people, 100% no good. (I know the percentages don't add up correctly, that's why I became an adjuster, my math wasn't good enough for engineering).

Those members of the society here with us today who have never met one of these unusual creatures should look around; there are some of them in the room today. They are easy to identify, just pick out the nearest person with three heads and a mean disposition and that's your man.

That's what one is, now a brief word as to what they actually do to earn a living. Very simply stated the facts that an aviation adjuster produces during his investigation of an aircraft accident and the recommendations he makes to the insurance carrier involved as a result of his investigation results in the disbursement of many millions of dollars each year. I might add that since the number of accidents that occur seem to increase as the number of aircraft in service increases the economic loss caused soley and directly by aviation accidents also grows larger each year. I do not mean to imply that the adjuster investigating the accident has the sole decision on spending this much money; however, he is and probably will remain the insurance industry's primary source of facts and evidence.

I see lips moving in the audience and they all seem to be saying "Dummy, why don't you read the NTSB report and findings of probable cause to get the facts!" Gentlemen, we do; however, most insurance carriers must live with the time limits incorporated in their policies. These time limits in many cases, are as short as 60 or 90 days. Since an insurance policy is a contract this means that in many cases 60 or 90 days after the crash we must have enough facts in hand to make firm decisions concerning contractural obligations. In the event of litigation, and you may be assured that there will be litigation arising out of any fatal accident, the adjusters investigation is the starting point for the defense of the insured party by counsel. At this point it should be noted that the insured party might be the pilot, the aircraft owner, the manufacturer of the aircraft or anyone else involved.

In brief, what I'm trying to say is that the adjuster and his factual investigation are vital to the aviation insurance industry now and will be even more important in the future.

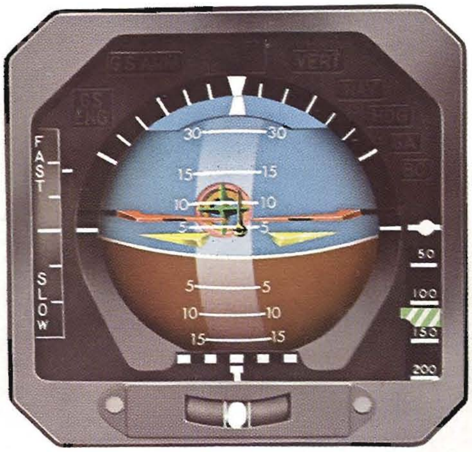
The dramatic growth of general aviation in the past 20 years and the problems associated with this rapid growth, is well known to everyone in this room. We now have more general aviation aircraft operating in the United States than the rest of the world have civil aircraft (excluding Russia and China). We are all familiar with the various market projections that industry has produced which show production of new aircraft increasing each year. Everyone here is very familiar with the fact that today, general aviation aircraft are much more sophisticated, fly higher, faster and contain more complex systems than did their counterparts of 20 years ago. 20 years ago, who really believed that we would have the number of high performance general aviation aircraft in service that we do today? Did anyone really believe that general aviation would include the number of jet aircraft that are now operating. I could go on concerning the improvements in the hardware during the past 20 years and how this has affected aircraft performance and flight safety as well as complicated the investigation of accidents; however, these things are well known to this group.

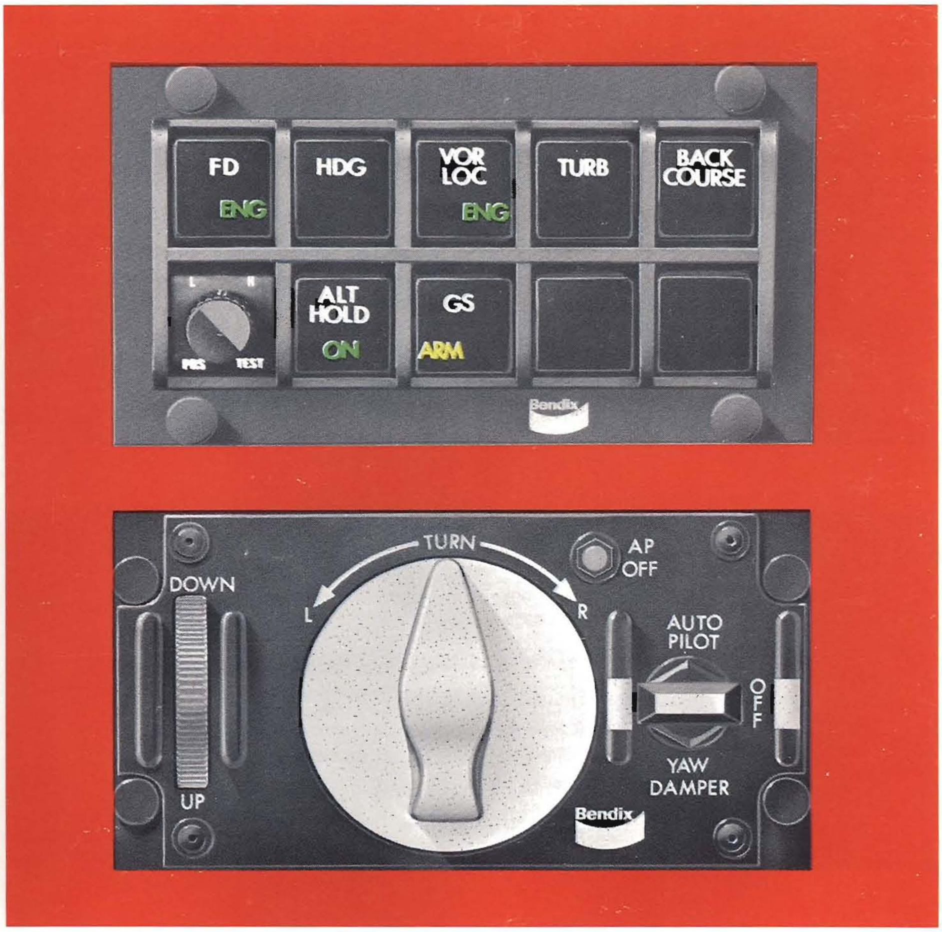
Obviously the aviati... adjuster of the future will become more and more involved in the technicalities of some of these systems. Also, obviously he will have to have more and more hard technical knowledge. Not that my company or any other insurance carrier expects any one man to be an expert in all phases of aviation, however, we do expect him to be knowledgeable enough to know when the need for an expert exists and where we can obtain the services of a qualified man. One of the goals of the Society of Air Safety Investigators has been the upgrading of the professional skills of air safety investigators and in my opinion this goal is being achieved through informal exchange of information by the membership. It is hoped that in the future even more can be done in this area.

I trust that the future will see more and closer cooperation between insurance investigators and governmental bodies during the factual portion of any aircraft accident investigation. In my opinion, such cooperation would be of benefit to all concerned and in the long run, would contribute to greater flight safety. For example, aviation insurers routinely require pilots to obtain additional instruction from CFR's when upgrading aircraft such as changing from fixed gear to retractable gear aircraft. There is no requirement in the regulations that this be done; however, we know that accidents can be prevented by such procedures and we make it a condition of policy issuance that this instruction be obtained. It is true that a requirement of this type is only enforceable after the fact; however, if an insurer doesn't pay someone $10,000 because he did not comply with a dual time requirement, we feel that this will impress that pilot (and any other pilots that he talks to) more than a token fine or a letter of reprimand.

Bendix FGS-70 Flight Guidance System

70 SERIES





Bendix **Navigation & Control Division**

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Bendix FGS-70 Flight Guidance System

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FLYING ON . . .

BOEING 747
FGS-70 Flight Director Instruments

VFW 614
FGS-70 Autopilot/Flight Director

CESSNA CITATION
FGS-70 Flight Guidance System

BH - 125
FGS-70 Flight Guidance System

KING AIR
FGS-70 Flight Guidance System

Millions of operational air miles flown by Bendix autopilots and flight directors—and more than three decades of concurrent design and production experience—logged by Navigation and Control Division engineering—back up the Bendix Series 70 Flight Guidance System (FGS). The Bendix FGS-70 implements evolutionary concepts for automatically controlling and directing the flight of modern, high-performance aircraft.

Precision Flying

The Bendix FGS-70 Autopilot/Flight Director provides all of the operational capabilities for flying the ATC system, radar vectoring and automatic approach with Category II accuracies.

During flight, the various modes permit automatic control, allowing the pilot time for other essential duties. Manual override permits the pilot to take over at his convenience.

The Flight Director, utilizing the Command Computer, has built-in-operational capability required for Category II criteria. The Attitude Director Indicator (ADI) features the Bullseye, a unique method of displaying localizer and glide slope raw data in the central portion of the instrument. This, together with mode status annunciation radar altimeter read out, makes the FGS-70 Flight Director a very complete system. A push-button Mode Control Panel for Autopilot and Flight Director simplifies control of the complete FGS-70 System.

Building-Block Options

The FGS-70 solid-state microelectronic design is based on the building-block principle, offering system configurations from a single flight director or autopilot to and including a dual flight director and monitored autopilot. This permits updating the system to future desires of the operator.

The configurations are:

- Single Flight Director
- Single Autopilot
- Single Autopilot/Flight Director
- Dual Flight Director, Monitored Autopilot

A single autopilot or flight director system is capable of Category II landings at 100 foot Decision Height (DH) and 1,200 foot runway visual range (RVR). Category II automatic landings are practical, utilizing any of the above configurations.

Self-Test Electronics

A method of electronic self-test, simplified trouble shooting, time proven by the airlines, is provided for FGS-70 customers. This allows on board trouble shooting of the electric boxes by simply pushing a test switch easily accessible on the front of the box. A fail lamp indicates the status of the box. It will extinguish in 28 seconds if the box is operative or will remain lighted if inoperative. Design of the boxes permits the use of portable test equipment to locate a faulty module. An inventory of modules, not boxes, offers a simplified and inexpensive approach to on-time maintenance.

Flexible Application

Identical FGS-70 components can be installed in many different aircraft types through adjustment provisions for system gains and the functional capabilities accessible thru external connections. This concept permits an operator to utilize the same black box configuration on more than one of his aircraft types. Servos are available to meet most aircraft requirements. These high-performance servos are universally applicable to all classes of aircraft, including high-performance modern jets.

Convenient front connectors facilitate troubleshooting, while front panel adjustments enable shop calibration of black boxes that accommodate the differences among aircraft types. Such features as microelectronic circuitry, channelized design, fail-safe control switching, and functionalized module grouping exemplify the latest state-of-the-art in the FGS-70 System. All equipment meets applicable FAA Technical Standard Orders (TSO). Even with autopilot engaged, the human pilot has control since smooth overpower forces are maintained at low levels.

Mode Control Panel for Automatic Operation

The Mode Control Panel allows the use of the Autopilot and Flight Director separately or combined for the various modes of operation. The Autopilot function with yaw damping and navigation coupling takes command of the aircraft and automatically maintains a prescribed flight path. The pilot can change the flight path in any mode without disengaging the Autopilot by use of the manual autopilot controls. He may also retain only the automatic function of yaw damping to increase the stability of his aircraft. Interlocks prevent engagement of incompatible modes, and ensure proper conditions in associated equipment for engagement of the autopilot function.

Pilot Selects Automatic Modes

With power and switching requirements satisfied, the pilot can engage any of the several modes made available for complete lateral and vertical control. Preengage synchronization of the Autopilot function allows engagement in a bank angle, and the Autopilot will roll the aircraft to a wings level attitude. Command modifiers allow the pilot to engage or disengage the Autopilot without disturbing the Flight Director functions and also prevents annoying transient aircraft motion.

Lateral Operation

With Pitch and Roll engaged

Yaw Damp–Damps out yaw oscillations and coordinates turns. It can function separately from Autopilot for rough air manual flying.

Heading –Enables pilot to preselect a heading other than that currently being flown. When Autopilot is engaged, current compass heading will be maintained.

VOR –Automatically engages, captures, and tracks radial selected and adjusts for wind direction.

Localizer –Automatically engages, captures, and tracks localizer radio beam selected, even under adverse conditions, such as windshear or crosswind.

Vertical Operation

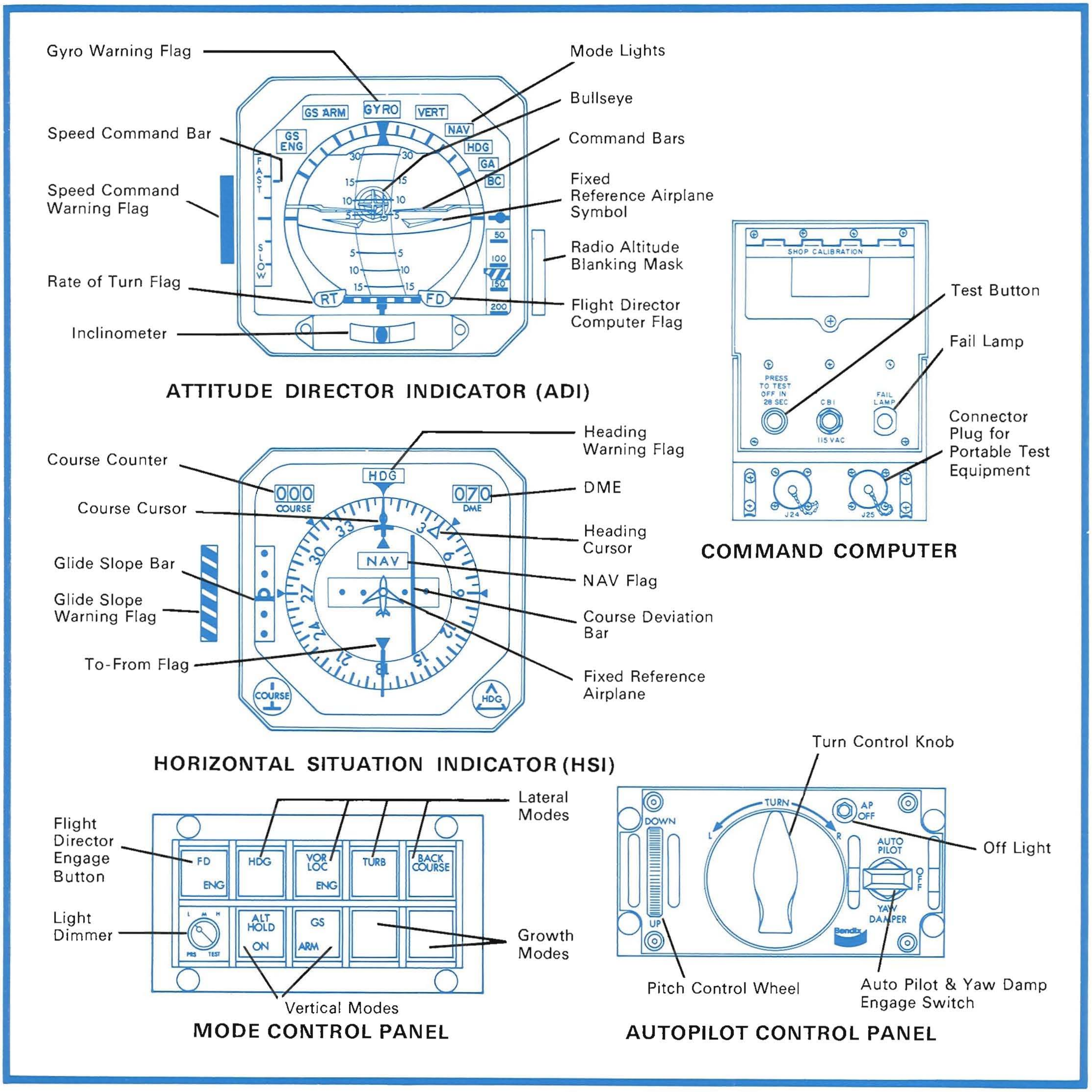
Pitch Attitude Hold–Maintains the pitch attitude existing at engagement.

Altitude Hold –Maintains the altitude existing at engagement.

Glide Slope –Automatically engages, captures, and tracks the glide slope beam.

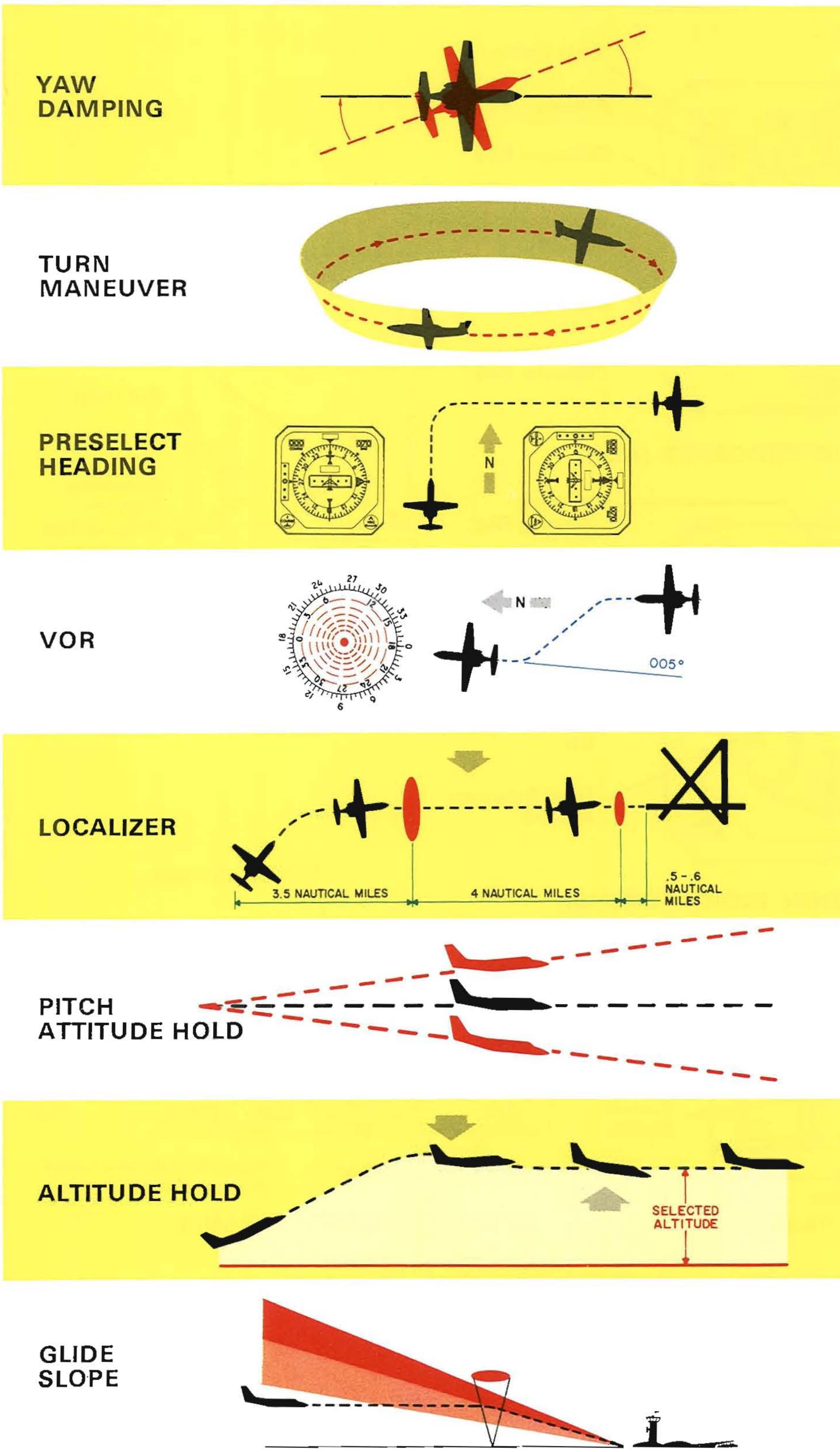
System Displays and Controls

3



Modes of Operation

4



Lateral Modes of Operation

Yaw Damp—This function may be utilized independent of pitch and roll channels and is advantageous in rough air when manually flying the aircraft. It couples the rudder servo to the rudder and produces a rudder deflection to dampen yawing oscillations and coordinates turns. The rudder pedals respond to all motions of the rudder.

Preengage Synchronization

The FGS-70 Autopilot versatility allows engagement without transients when aircraft attitude is not wings level. This is achieved by preengagement synchronization. If engagement is at high bank angle, compass heading will lock in at 6°.

Manual Flight

After Autopilot engagement, turn maneuvers are initiated by rotating the turn knob on the Control Panel in the direction of the desired turn. The heading reference drops out, and the aircraft assumes a right or left bank angle. This is maintained until the knob is returned to detent, which then reengages the heading reference at the new compass heading. Small bank angles are implemented by merely moving the knob out of detent.

Heading (HDG)

This enables the pilot to select a heading reference other than the engaged heading. The reference is set on the Horizontal Situation Indicator (HSI) by the HDG knob moving the heading cursor. When the heading is engaged, the aircraft maneuvers smoothly to the desired heading. System flexibility permits the pilot to command further heading changes, again using the HDG knob, while the mode remains engaged. A command modifier limits roll rate to a comfortable level upon initial engagement or subsequent heading changes. This flexibility is invaluable in accomplishing holding patterns, radar vectors, procedure turns, GCA approaches, and enroute NAV/AID transitions.

VOR

It automatically engages, captures and tracks the radial selected by the pilot on the aircraft's Horizontal Situation Indicator. It also corrects for crosswinds by computing the crab angle required to track the beam and provides additional smoothing during station passage.

Localizer

This automatically engages, captures and tracks the localizer radio beam selected by the pilot. It compensates for such adverse conditions, as windshear, crosswinds, out of trim, or asymetrical power.

Vertical Modes of Operation

Pitch Attitude Hold—Stabilizes the aircraft at the pitch attitude existing at the instant of engagement. The pilot can manually initiate a pitch maneuver at any time during autopilot engagement by rotating the pitch wheel from detent, causing system interlocks to disengage any existing vertical modes. The aircraft assumes a nose up or nose down pitch rate proportionate to the amount and direction of rotation of the pitch wheel. The system provides limits to control the maximum pitch attitude commanded and this angle will be held, or until the wheel is moved or other modes engaged.

Glide Slope—In conjunction with the localizer mode, the FGS-70 automatically controls the aircraft to fly to and track the glide slope beam. The glide slope engagement is automatic. Easy-on circuits prevent engaging transient commands and provide correct gain scheduling as beam convergence occurs during the approach.

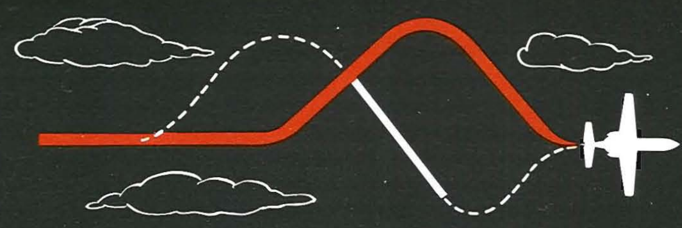
System Implementation

Power Distribution—Power isolation is provided by having an independent yaw axis power supply in the Control Computer and separate power supplies for the Control and Command Computers.

Switching—The engage switch is fail safe. The pilot may be assured when in the Off position; all servo clutch solenoids are grounded, guarding against hot wire type failures. In the yaw damper position, only the rudder clutch solenoids can be activated.

Fail Safe—Indication of automatic disengagement is designed into the warning-light circuitry. When either the Yaw Damper or Autopilot is disengaged, for any reason other than pressing the wheel disconnect switches, the warning light would go on. To extinguish the warning light, the pilot must press the wheel disconnect switch, thereby acknowledging the disengage status.

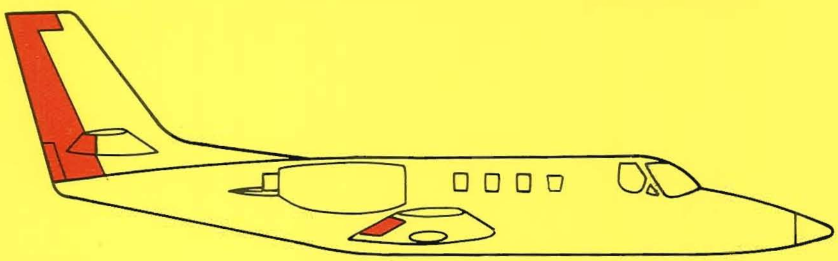
Operational Capabilities



Rate Displacement Control

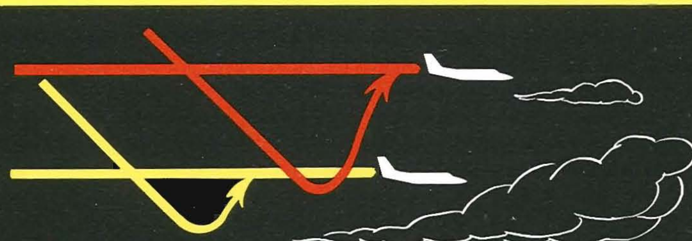
The FGS-70 supplies displacement combined with rate control for tight, positive, and accurate control of the aircraft. Rate allows the use of increased autopilot gain for increased sensitivity and faster response.

Rate-displacement starts correcting fast; thus it reduces error excursion. It dampens to increase control stability; it is unaffected by the aircraft's structural movement.



Parametric Gain Adjustment

Autopilot gains continuously change in response to the varying airspeed factors that surround a swift-moving aircraft. Approach control at descent is desensitized as a function of time or radio altitude logic. The FGS-70 thus adapts and responds more precisely and more efficiently than is possible for the human pilot.



Integration Control

Steady-state error is automatically corrected. Error and time are linearly integrated for computer control and counteract wind, trim changes, and the other variables that prevent an aircraft from maintaining a prescribed path. It automatically adjusts for crosswinds in VOR and LOC navigation and compensates for the variable conditions that cause altitude and glide slope errors, thereby eliminating steady-state hang-off errors in both roll and pitch axis.

The FGS-70 Autopilot Is Designed By Bendix To Be A Versatile System Capable Of Providing Automatic Flight Control Over A Wide Range of Subsonic Aircraft. Computational Functions Are Provided For Autopilot, Or Flight Director, Or Both Simultaneously.

OPERATIONAL CAPABILITIES

System Engagement

Attitude: Roll—normal 0 degrees, capability ±60 degrees
Pitch—normal 0 degrees, capability ±20 degrees

Manual Mode

Turn Knob—±30 degrees of roll attitude.
Pitch Wheel—±20 degrees
Turns—unlimited

Altitude Hold

Engagement—at any pitch attitude will hold altitude at time of engagement.

Heading

Engagement—with unlimited heading commands.
Heading Changes—unlimited in either direction.

VOR

Variable angle intercept—permits pilot to approach beam from any angle.

Engagement—is automatic as aircraft moves within beam saturation (2 course deviation dots).

Crosswind—crab angle corrections for 25 degrees of heading.

Localizer

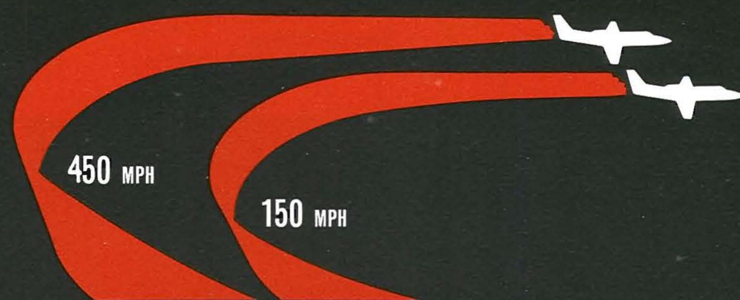
Engagement—will capture at all angles. Normal capture is at less than 90 degrees and a beam displacement of ±2 course deviation dots on HSI.
Crosswind—corrections for 25 degrees of heading.
Heading intercept—variable angles in heading for capture of localizer.

Glide Slope

Engagement—normal at intercept angles of less than 5 degrees and a beam displacement of approximately one needle width (15 ua) or less.

Station Passage

Smooth station passage is made without switching to the heading mode. The pilot stays in VOR mode and changes course while passing over the cone. This is accomplished with small bank angles and minimum heading changes by sensing the beam divergence and increasing the beam smoothing while at the same time lowering the beam authority.

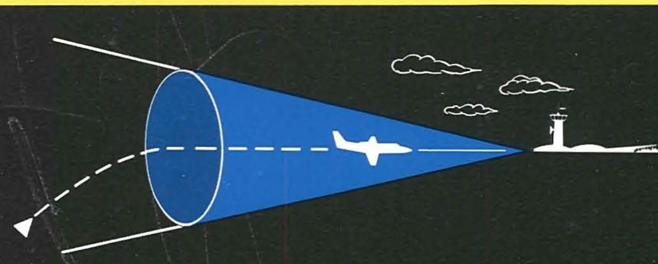


Coordinated Maneuvers

Automatic coordination of aileron and rudder in all turns, either by controller, radio command, or heading control, is provided at all airspeeds within the range of the aircraft. Altitude compensation, proportional to bank angle and airspeeds, maintains constant altitude in turns.

Pitch Axis Stability

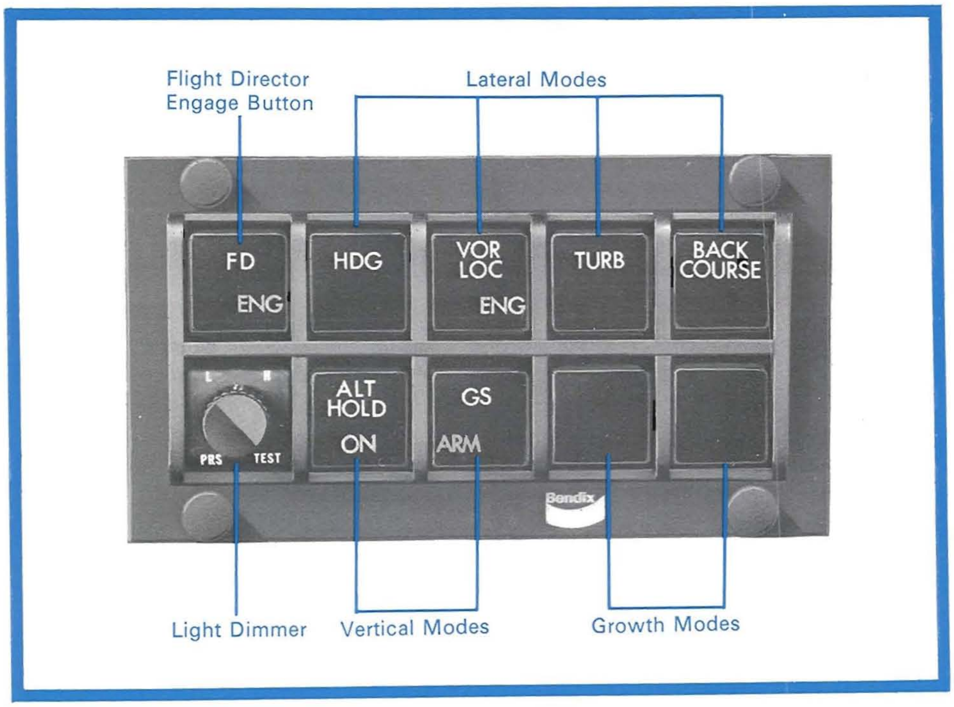
High-level servo-loop gains are attained to provide exceptional pitch axis stability through pitch rate gyro damping. This is enhanced by a position transmitter for accurate positioning of the control surface. Where required, lag control is available for reduction of longitudinal oscillations.



Automatic Approach

The localizer beam can be automatically captured from any angle through the combined use of beam displacement, runway bearing, and integration control functions. Bank angle is limited.

Glide Slope is automatically captured, and the Vertical Mode drops out, allowing a smooth transition to Glide Slope engage. As the aircraft approaches the runway, desensitization provides correct gain scheduling.



Flight Director Switch (FD-ARM/ENG)

Depressing this button will ARM the Flight Director if no lateral modes have been selected. Selecting a lateral mode, such as HDG and VOR/LOC will immediately engage the system, and the command bar will be displayed on the Attitude Director Indicator.

Heading (HDG)

The heading mode commands the aircraft to capture and maintain the heading set on the Horizontal Situation Indicator (HSI). New headings may be selected at any time and will result in the aircraft turning to the new heading.

VHF Omni Range (VOR/LOC)

Selection of this mode furnishes automatic, engage, intercept and tracking of VOR radials or localizer courses selected on the Horizontal Situation Indicator (HSI). Flying through the VOR cone, the FGS-70 suppresses the unstable signal and automatically captures course and track outbound on desired radial.

Turbulence (TURB)

This switch provides the pilot with a means of reducing the autopilot gain to eliminate uncomfortable control movements of the aircraft during turbulence. Selection of TURB drops out all other modes except heading (HDG) and disconnects all air data compensation.

Back Course (BC)

The back course configuration allows utilization of back course approach procedures. Engaging the button reverses the course error and localizer signals for proper sensing.

Mode Light Switch

This is a three-position rotary switch that provides L (low), M (medium), and H (high) intensity for the mode status lights in the ADI and the lower section of the mode select button lens. Additionally, pressing the knob will illuminate all mode lights for a bulb integrity test.

Altitude Hold (ALT HOLD)

Engagement of the altitude hold mode permits the aircraft to maintain the pressure altitude existing at the moment of selection. This mode can be used with the lateral command modes. In approach mode, altitude hold will automatically disengage at glide slope engagement. In this mode the VERT (vertical) light on the Attitude Director Indicator will annunciate.

Glide Slope (GS)

Glide slope arm, capture, and gain programming are combined with localizer capture during the approach. Switching from glide slope ARM to ENG is automatic at the appropriate point relative to the beam. Easy-on circuits allow smooth capture with minimum overshooting. Desensitization provides correct gain scheduling for the entire approach.

Go-Around Button

Pilots Pitch Command reference for Flight Director only.

This is a command bar attitude synchronization that is used in the Flight Director ADI. Pressing the synch button on the pilot's control yoke will synchronize the command bar to the aircraft attitude at that moment, thus establishing the pitch reference. Pitch synchronization is normally used with lateral modes except during glide slope capture.

Autopilot Control Panel

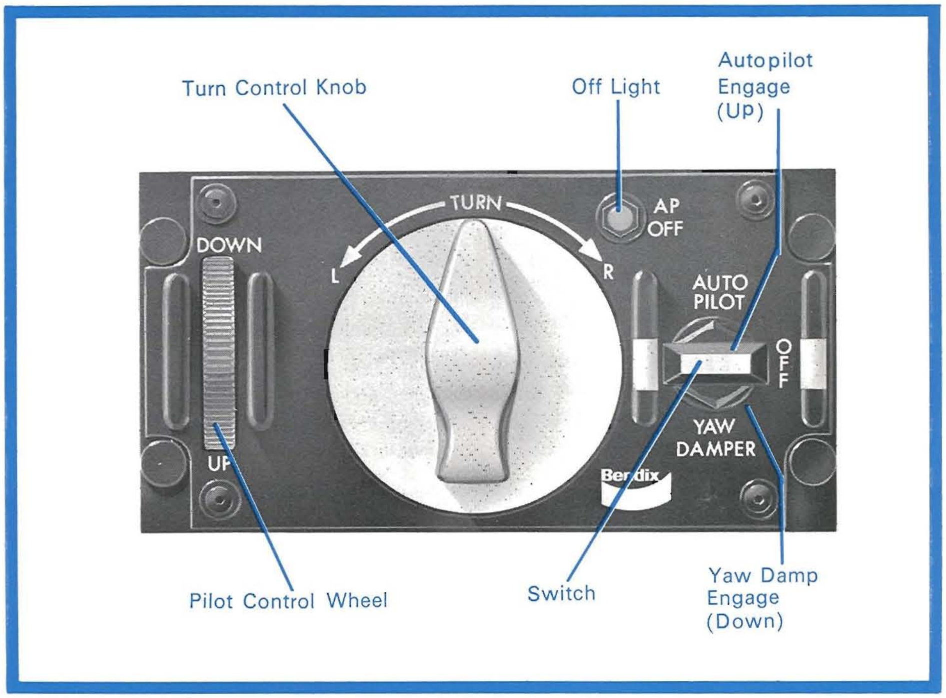
OPTIONAL MODES

Indicated Air Speed Hold (IAS)

The indicated air speed existing at the moment of engagement will be maintained. This mode is useful for most efficient rate of climb through lower altitudes.

Mach Hold Mode (MACH)

Efficient climbs and precise descent speeds can be maintained at higher altitude with MACH hold mode. Data from an air data source to the flight computer provides the MACH number reference existing at MACH hold engagement.



Pitch Wheel

It provides convenient finger-operated pitch attitude rate control without over control. Aircraft rate is proportional to wheel displacement and guards prevent accidental operation. When the wheel is turned and moved out of detent, it disconnects the engaged vertical mode.

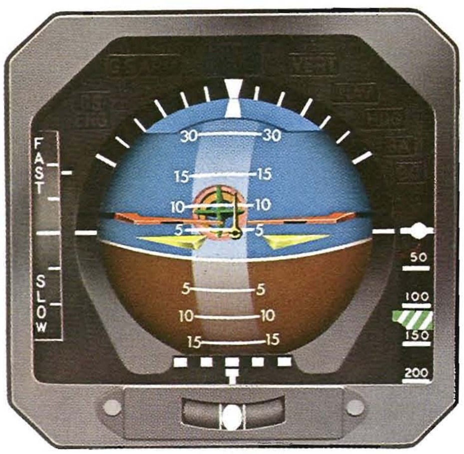
Turn Knob

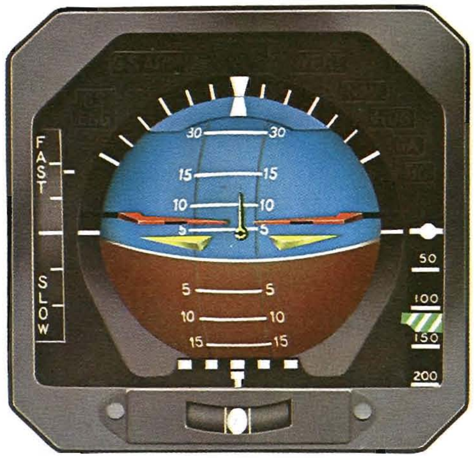
This knob allows full aircraft bank maneuvers by rotating a quarter of a turn in either direction. Pilot may rotate knob full turn, and the aircraft will limit bank to 7 degrees per second. The knob straight up is in detent position, and movement from this position will disconnect any engaged lateral modes. Dependent upon lateral mode configuration, when the knob is in detent, compass heading is engaged.

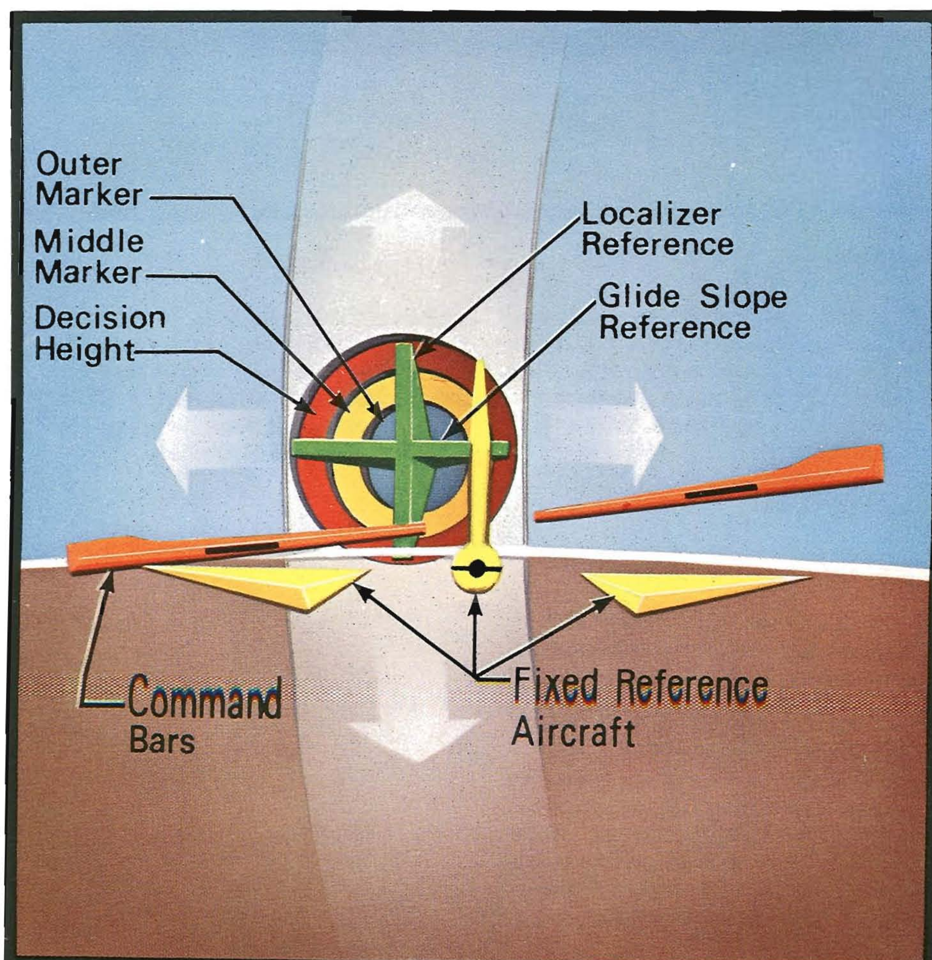
Engage Switch

This is a three-position, center off, solenoid-held switch with mechanical advantage to permit pilot override when desired. Yaw Damping (DAMP) alone or the complete autopilot (AP) may be engaged separately.

Attitude Director Indicator (ADI)







The Attitude Director Indicator displays aircraft attitude, computed roll and pitch steering commands, and ILS information through a Bendix exclusive—the Bullseye Display.

The Bullseye, a significant development in the technology for all weather landing, concentrates in the center of the indicator a display of expanded localizer and glide slope information as raw data. The Bullseye automatically comes into view in less than one second when the glide slope is engaged; automatically rotates out of view when in go-around and cruise modes.

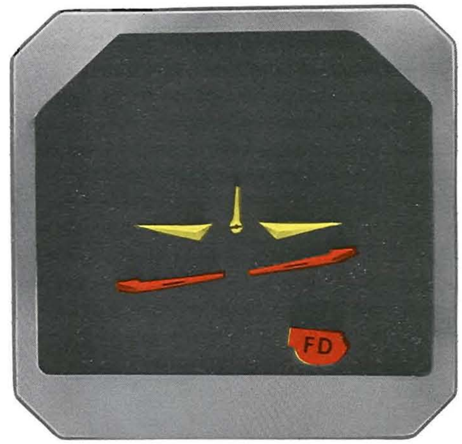
The Bullseye Display consists of a three-dimensional cross pointer that simulates the localizer and the glide slope beams. The cross pointer mounts in a recessed cone consisting of three colored rings. The rings illuminate as the aircraft progresses down the glide path and indicate aircraft positions at the outer marker (blue), middle marker (yellow), and Decision Height (red).

During the approach, when the fixed yellow dot in the center of the instrument is in the vicinity of the Bullseye cross pointer, the aircraft is positioned correctly on the approach path. At 100 feet above runway altitude, when the yellow dot is within the outer (red) ring of the Bullseye it indicates the aircraft is within FAA Category II approach limits and, therefore, may continue to land.

Category II Operation

Requirements call for the aircraft to be within the confines of a window at 100 feet above runway altitude. This Category II window is defined as ±75 microamps or 22 feet from glide slope beam center and ±25 microamps in localizer.

Movement from the center position of the Bullseye of one radius is ±75 microamps in glide slope and ±25 microamps in localizer. Most important is that, at 100 feet, movement of less than one radius from the dot on the fixed referenced tail is the indication that Category II window is achieved. The outer circular red light at this moment, clearly indicates the relative positions of the outer ring and the fixed reference.



Three-Dimensional Sphere—The Attitude-Horizon Sphere moves against aircraft fixed reference to display aircraft pitch and roll attitude.

Aircraft Fixed Reference—Provides a wings and tail symbol to display movement of the sphere in pitch and roll attitudes.

Roll Attitude Indexes—Display actual roll attitude through movable index and fixed reference marks. Shown above as 10 degrees right roll.

Gyro Warning Flag—Displays that attitude information is reliable. This is accomplished by servo loop monitoring.

Inclinometer—Ball indicates slip or skid condition of aircraft.

Flight Director Command Bars—Positioned by signals from the computer to display integrated pitch and roll steering commands in the particular mode selected. Automatically recessed out of view when flight director system is not in operation.

Aircraft Fixed Reference—When the command bar moves, pilot positions the aircraft to align with the fixed reference wings and tail.

Flight Director Warning Flag (FD)—Displayed when command bar information is unreliable.

Speed Command—For the approach, an easily interpreted scale to display speed command is located on the left side of the indicator. The bar index moves up and down against a fixed scale and alignment with the center indicates aircraft is at commanded air-speed. The bar is recessed out of view when not in use. A mask covers the speed command function when in-operative for any reason.

The above illustration denotes the air-craft is faster than the command.

Radar Altimeter—Index moves vertically against a fixed scale to indicate height during final phase of approach. At 220 feet the green cross hatched bug moves into view; shown above at 110 feet. When inoperative or during cruise over 1000 feet, the display is masked out of view.

Rate of Turn—Indication for rate of turn is situated on lower part of ADI. Displacing one square represents 90 degrees of turn per minute.

Rate of Turn Warning Flag (RT)—Displayed when system power is off or inoperative due to system failure.

Annunciators—The appropriate annunciator illuminates to indicate the particular mode of operation selected. Since the FGS-70 has automatic switching in several modes of operation, the annunciation updates the pilot when this occurs. All lights illuminated for illustration purposes only.

GS ARM—System armed for automatic Glide Slope engage.

GS ENG—System has automatically engaged Glide Slope.

VERT—Altitude Hold mode is engaged.

NAV—VOR or Localizer mode is engaged.

HDG—Heading mode is engaged.

GA—Go-Around mode is engaged.

BC—Back Course configuration has been selected.

Horizontal Situation Indicator (HSI)

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The Horizontal Situation Indicator presents aircraft displacement relative to VOR radials, localizer, glide slope beams, and conventionally presents heading references. Preselect heading and preselect course knobs permit rotation of the appropriate cursor to any desired point on the compass card. A DME counter displays distance to a station.

Compass Card—Rotates with aircraft from 0 to 360 degrees. Azimuth ring is graduated in 5-degree increments.

Lubber Line Markings—Fixed at fore and aft positions.

Azimuth Markings—Fixed at 45, 90, 270, and 315 degree bearings.

Aircraft Fixed References—These are fixed positions corresponding to longitudinal axis of aircraft and lubber line markings. Serves as reference for course deviation and glide slope displacement needles.

Heading Cursor—Triangular cursor positioned on the compass card by heading knob, to select and display preselect compass heading. Rotates in set position with compass card.

Heading Knob—Positions heading cursor. Simultaneously sets internal system reference for flight director commands in heading mode of operation.

Heading Flag—Displayed when compass system is off or heading indication is inoperative.

Course Cursor—Inverted T cursor positioned on compass card by course crank to select and display VOR or localizer beams. Rotates in set position with compass card.

Course Counter—Set simultaneously with course cursor by course knob for digital reference.

Course Knob—Positions course cursor and course counter. Simultaneously sets internal system reference for flight director commands in VOR or localizer modes of operation.

Course Deviation Bar—Rotates in relationship to aircraft heading. Displays both angular and lateral displacement for VOR localizer beam.

Course Deviation Dots—Serve as displacement reference points for course deviation needle.

To-From Flag—Two flags 180° apart. One always points to or from station when operating on VOR.

NAV Warning Flag—Displayed when NAV receiver is inoperable.

Glide Slope Bar—Displays displacement from glide slope beam. It is in view only when in localizer mode.

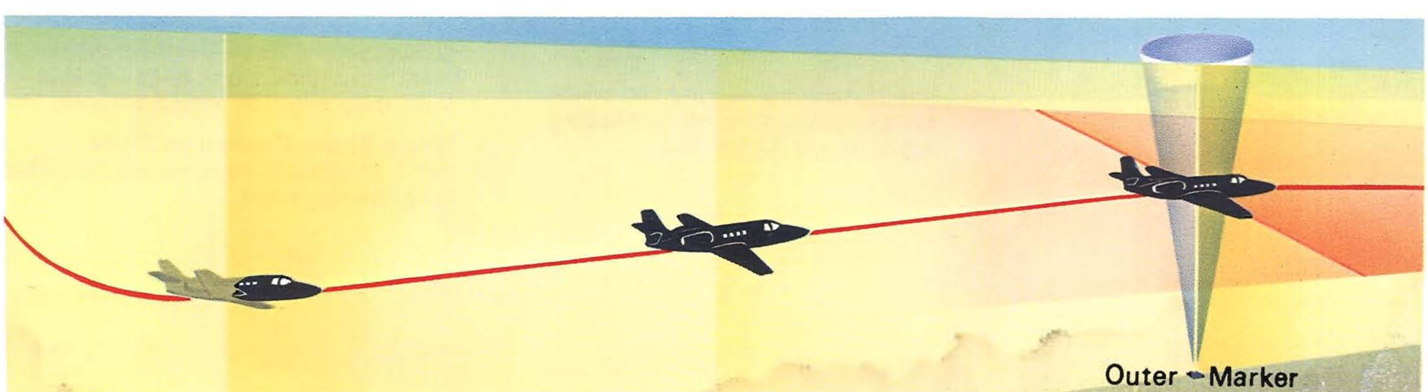
Glide Slope Deviation Dots—Serve as displacement reference points for glide slope bar.

Flying the Localizer and Glide Slope

Aircraft turning from a heading of 105° to intercept localizer on 060°. The flight director command to fly left satisfied; Nav. light on; localizer captured.

Aircraft wings level and slightly left of localizer. Localizer is engaged and glide slope is armed. NAV, VERT, and GS/ARM annunciator lights on.

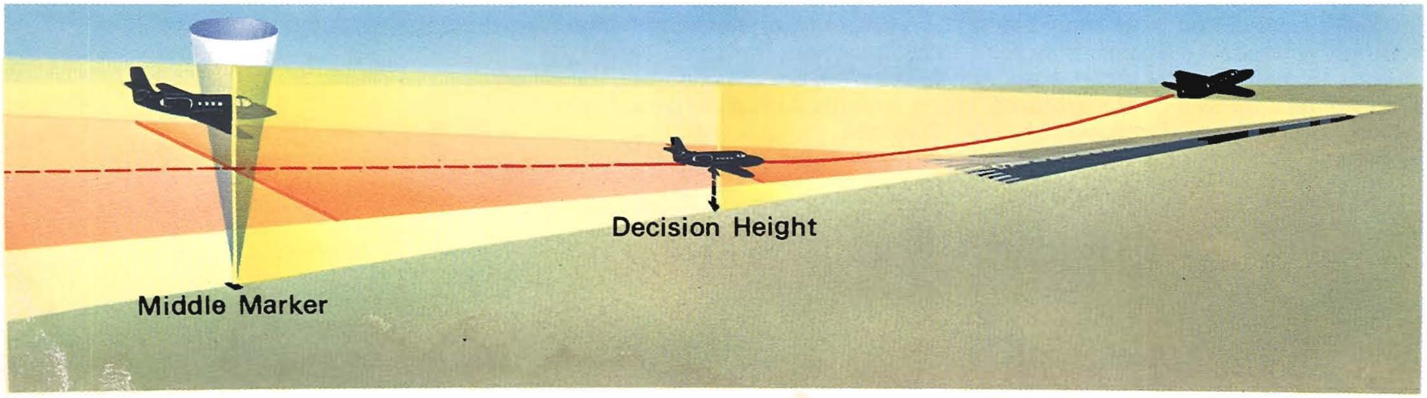
Aircraft at outer marker, wings level, glide slope engaged. Bullseye rotated into view, inner blue light illuminated, depicting arrival at outer marker. Center position of Bullseye indicates aircraft precisely on localizer and glide slope. NAV and GS ENG annunciator lights on.



Aircraft at middle marker, indicated by center yellow light in Bullseye. Wind shear has positioned aircraft above glide slope and to left of localizer. Shown by cross pointer relative to fixed reference aircraft. Flight director commands fly down and right.

Aircraft alignment corrected and has proceeded to the Decision Height (DH). The Bullseye outer red light on, indicating DH. Fixed reference yellow dot within red ring signifies aircraft in position to land.

Runway blocked, aircraft must go-around. Pilot depresses Go-Around button on control wheel, activating Command Bars on the Flight Director to command a fly up, wing level attitude. The Bullseye retracts from view, GA light comes on, and other modes drop out.



FGS-70 Block Diagram

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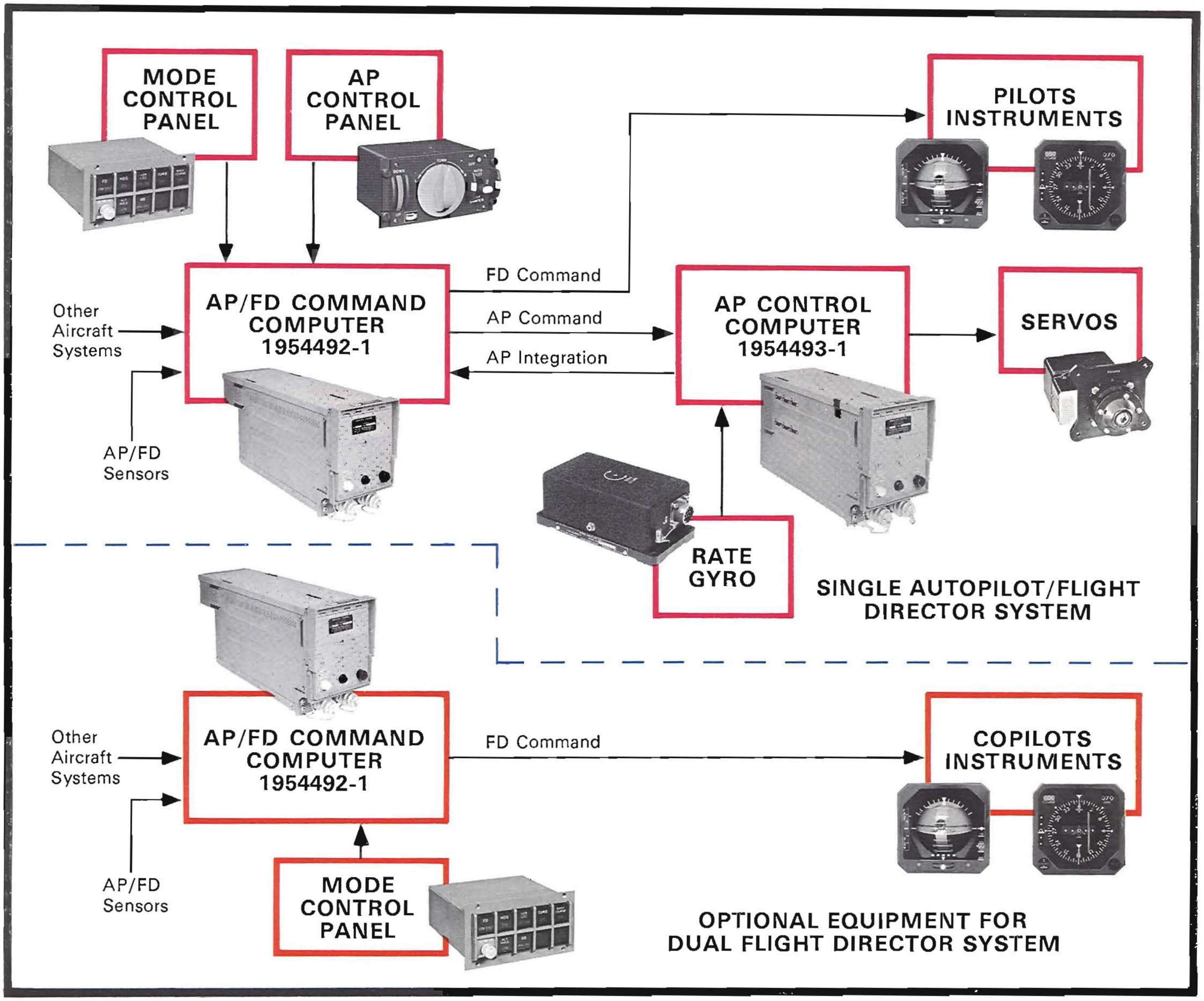

The FGS-70 System configurations flexibility is based on a building-block concept, whereas a customer may purchase a single Autopilot with Category II capabilities up to a dual monitored system for Category II automatic landings.

Illustrated in the above block diagram is a single Autopilot/Flight Director configuration; indicated below the broken line are the additions necessary for a single Autopilot/Dual Flight Director.

Features

Autopilot

- Automatic pitch attitude, compass heading, and altitude hold
- Independent yaw damper operation
- Category II ILS with built in growth capability for Category II Automatic Landing
- Automatic capture and tracking of VOR radial
- Automatic self-test for electronic boxes
- Roll command rate limiting
- Automatic Capture and Track of ILS localizer and glide slope beams
- Lift compensation in turns
- Preselect Heading
- Automatic turn coordination
- Turbulence mode
- Manual control for pitch attitude and turns
- Automatic pitch trim
- Roll and pitch command limits
- VOR data smoother for beam bending and noise
- Autopilot gains automatically adjusted with airspeed
- Smooth VOR station passage
- Integral fail-safe interlocks

Flight Director

- Bendix Bullseye displays raw data ILS information on ADI
- Common Mode Control with Autopilot
- Provides Category II operation, including go-around capability
- Radar Altimeter readout on ADI
- Extensive in-line monitoring for pilot confidence
- Fast-Slow display on ADI
- Common computer with Autopilot
- Back Course Operation
- Go-around capability through programmed or computed pitch commands
- Integrated pitch and roll commands
- Prominent warning flags, logically integrated for maximum accessory equipment monitoring
- Automatic crosswind compensation
- Windshear capability exceeds FAA requirements
- Roll and pitch attitudes, roll and pitch FD commands
- Fail-Safe interlocking for mode selection

Other Bendix Precision Equipment For Navigation

Bendix also makes available a companion system that forms part of the family of the Series 70 Navigation and Flight Guidance Systems—the CB-70 Compass System. The CB-70 provides directional references for navigation with precision and optimum reliability.

Navigational Instruments

- Three-Inch Standby Attitude Gyro Indicator—A self-contained, electrically driven, non tumbling, integrally lighted indicator.
- Radio Magnetic Indicator (RMI) and Radio Magnetic Direction Indicator (RMDI)—Multipurpose navigational instruments that display magnetic bearing of the aircraft and two, radio reference points.

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THE STAN(R) INTEGRAL WEIGHT AND BALANCE SYSTEM
"AN UNPRECEDENTED SAFETY ADVANTAGE"

BARRY J. HAWKINS

STAN Sales Manager
Fairchild Industrial Products

INTRODUCTION

The title of this paper--"The STAN Integral Weight and Balance System--'An Unprecendented Safety Advantage'"-- is actually a quotation from the first test report ever written about the STAN system. In a foreword to the report which covered testing of an early version of the STAN on-board aircraft weight and balance system the author, Capt. Scott Flower then Chief Pilot Technical for Pan American World Airways said: "Knowing an aircraft's actual takeoff gross weight and center of gravity prior to takeoff offers an Unprecendented Safety Advantage to the crews. Such a system (STAN) is described here."

The report covered the official test program which introduced a new era in aircraft technology--Integral Weight and Balance Systems. From that point in 1963 to the present, great strides have been taken ... but much remains to be done.

In previous papers on this subject I have described the STAN system in great detail. However I assume the Society of Air Safety Investigators is not so much concerned with how it works and what comprises it as with what it can do in the way of accident prevention and as an aid after the fact. I will, therefore, not dwell too much on these aspects of the system. Instead, a few brief remarks plus the literature and display material we have brought with us should adequately describe the system for you.

STAN, first off, is an acronym which was coined for easy reference. The four initials stand for <u>S</u>ummed <u>T</u>otal <u>A</u>nd <u>N</u>osegear and refer to the method in which aircraft takeoff gross weight and center of gravity is determined with the system. The total weight sensed by each landing gear is SUMMED and in the computation of center of gravity, the NOSEGEAR is used separately in the process. The basic STAN system consists of a pressure transducer mounted on each landing gear oleo strut which sense the oleo pressures in the struts. These pressures are converted into electrical signals which are transmitted through cable assemblies into the cockpit mounted computer. This small computer/ display box which we call an Indicator Control Box or ICB--accepts these signals and, through a resistor network and logic circuitry sums the transducer signals. This value then becomes the basis for the Take Off Gross Weight (or TOGW) display. To compute center of gravity in terms of percent of Mean Aerodynamic Chord (% MAC) the nose gear transducer signal is utilized again in the computation in a standard moment solving equation. % MAC is displayed on the ICB simultaneously with TOGW by large, easily legible Light Emitting Diode displays. Thus, each time the computer is activated the system weighs the aircraft as if it were on a giant scale with excellent accuracy and reliability. STAN systems have been operational in fleet use by many of the world's leading airlines since 1965 and we have well over 3 million operational hours to our credit on STAN equipped aircraft. Of prime interest to you as Safety Investigators is that NO STAN EQUIPPED AIRCRAFT HAS EVER BEEN INVOLVED IN AN ABORTED TAKEOFF OR ACCIDENT WHERE WEIGHT AND/OR CENTER OF GRAVITY WAS AT FAULT OR A CONTRIBUTING FACTOR. Unfortunately, however, only about 5% of the transport category aircraft flying today are STAN equipped while the statistical growth of air accidents where weight and balance is a factor, is increasing.

ACCIDENT STATISTICS

Aircraft takeoff and landing accidents over the last 12 years have become a major cause of fatalities and substantial aircraft damage. In official papers and reports from the National Transportation Safety Board, International, Canadian and U. S. Air Line Pilots Associations, the British Air Registration Board and similar sources, data pertaining to aircraft accidents have been compiled by the writer as source material. From 1959 through 1970, for example, 141 transport category aircraft accidents occurred of which 32.5% took place during the takeoff and climbout phase and 51.7% during the landing and rollout phase. Of the 46 recorded takeoff accidents 19 could be construed as weight and balance accidents--often, of course, associated with other factors. This constitutes 43.5% of the total. In the landing and rollout phase, documentation shows that 2 of the 73 landing accidents were the result of improper weight and balance--a condition which probably existed at takeoff but which was not serious enough to cause an accident at that point. A summary of these accidents is available.

NTSB statistics covering U. S. Civil Aviation for the six year period of 1964 - 1969 show that over 200 accidents occurred where weight and balance was the single cause or contributing factor. Of these, more than 50% were fatal to the occupants of the aircraft. While the majority of these accidents occurred to smaller aircraft, several hundred people were killed by this unseen threat.

From the military standpoint and covering a shorter period of time, the U. S. Army Board for Aviation Accidents Research (USABAAR) reports over 140 accidents involving U. S. Army aircraft due to weight and balance errors occurred. USAF indicated that 12 actual weight and balance accidents occurred during a relatively short time span. Navy has not furnished us with statistics but we are sure that they are comparable from discussions we have had with Naval Air Safety representatives.

Of perhaps more significant than the basic figures is the fact that the incidents are growing in number--from one weight and balance accident for transport category aircraft reported in 1959 to an average of 2.5 in the last few years. When it is considered that aircraft are getting larger and are able to carry more passengers and payload, the losses associated with this increased incidence of accidents are proportionately much greater than in early statistics.

To put transport accidents into another frame of reference, in 1970, one accident occurred for every 515,000 hours flown. For weight and balance causes, one aircraft was lost for every 3,262,000 hours flown.

STAN AND THE AIR SAFETY INVESTIGATOR

What does this mean to the air safety investigator? Off hand it might seem that an effort is being made to put many of you out of work! Frankly none of us would object if there were never another aircraft accident but as long as airplanes fly and people fly them and ride on them there will be accidents. The STAN system--or any other working integral weight and balance system--can, however help prevent an accident from occurring and, at the same time, can provide for greater economies of flight operations through at least 6 separate operational facets which are supplemental to this discussion. As a SAFETY tool however, STAN acts as a monitor on the aircraft weight conditions and alerts the crew members to an overload or a mis-loaded condition--prior to starting that critical takeoff run. If, prior to takeoff, each captain has the opportunity of ascertaining the exact weight and balance condition of his aircraft or of double checking the load sheet or manifest form handed him by ground personnel prior to his taxiing away from the blocks, two things can happen. The captain can confirm that his aircraft's weight and balance are within operational limits for the takeoff and hence can correctly compute his in-flight and landing weight and c.g.--or he may discover that somebody made an error in the load sheet and his airplane actually weights 10,000 pounds more than the paperwork says and, to make matters worse, his center of gravity is too far aft for safe takeoff. In case after reported case where these conditions have occurred, the captain has refused to takeoff until the complete loadsheet has been re-checked and the aircraft loading corrected. The object lesson--"knowing an aircraft's takeoff gross weight and center of gravity just prior to takeoff offers an unprecendented safety advantage" is well learned.

While on the subject of pilot's comments when they find that STAN does not agree with the load sheet, permit me to cite a few choice quotations from data forms which we have obtained from STAN equipped aircraft during early service testing of the systems:

From PAN AM: STAN found Error; STAN correct; scales used--extra weight found; weight and balance form in error; extra weight found; extra fuel in weight and balance; STAN believed correct; tail heavy on takeoff--STAN more correct than manifest; STAN computed right; Re-weighed pallest--STAN right; extra weight found. . . etc, etc.

From BEA: STAN has highlighted major loading errors on six occasions so far (after less than a year of operation).

From ONA: "RIGHT ON"; % MAC of STAN was correct; STAN on the money; STAN TOGW very accurate; Suspect not loaded as usual; Manifest, % MAC suspected in error; Weight and CG very close to STAN; Fuel totalizer 1200 (1500, 500) pounds more than paperwork as STAN indicated. STAN TOGW seems correct due to power required for airspeed in cruise and takeoff; plus a few less serious comments such as "Mama Mia atsa STAN."

TWA: Works Well; works good; looks good; this system works very well; pilot reports IWBS (STAN) c.g. appears more correct.

And from a corporate business jet operator: "I have found the STAN MAC readout in % to be of great value to arrive at a more accurate elevator trim setting for takeoff. The TOGW has confirmed our fuel, passenger and baggage load factor and therefore makes our V speed selection more accurate. My flight crews and myself endorse the system and application on the G-II".

Other remarks made in person to me indicate that many many overloaded aircraft have been rejected by the flight crews since STAN has been aboard and they are standing fast on refusing to fly until the discrepancies are corrected. Safety preventative action, therefore, is becoming more fully realized as crew become more reliant on STAN and its accuracy.

How can STAN or any IWBS help in accident investigations? As you know one of the many records kept for each flight is the load sheet, or manifest form which is immediately acquired by the investigative team once an accident has occurred. The question then becomes one of ascertaining the degree of accuracy of the paperwork compared to the actual aircraft loading. Fuel aboard at takeoff can be fairly well documented by various inputs outside the manifest sheet as can numbers of passengers and approximate numbers of bags. The aircraft's last known empty operating weight can be established from weight control records. There are, however a variety of unknowns which can crop up in any manifest or load sheet which only an on board weight and balance system can establish. The use of average passenger weights, for example, is being looked into with greater intensity in recent months as has the use of average baggage weight per passenger. Another source of error which frequently does not show on the manifest form is carry on baggage. This growing trend is being fostered as aircraft become more adaptable to accepting carry on luggage and special containers are set aside to stow large briefcases, small suitcases, innumerable clothes bags, assorted cartons and boxes, etc. which the average passenger always seems to have with him when he climbs on an airplane. One pilot flying international routes described his normal takeoff in very hot conditions with temperatures exceeding 100°F as "a hypnotic trance, mesmirized by the slow acceleration and the ever reducing length of Tarmac ahead." He was speaking of his not unusually overloaded flight. In cargo flights, discrepancies in weight and balance are especially prevalent since shippers manifest often are only approximates of actual weight, loads are put on the aircraft contrary to the load plan and the task of manually determining the aircraft's weight and balance is arduous, time consuming and complex.

Recognizing that errors occur in load manifests and that hundreds and even thousands of pounds unaccounted for can be aboard an aircraft and not on the paperwork, how does the safety investigator reconcile this information--or for that matter obtain it in the first place? In some accidents where total destruction of the aircraft and passengers does not result, a realistic weight and balance calculations can be performed on the wreckage and from passenger records.

Where the aircraft is totally destroyed, however, the only record of the flight's weight and balance presently available is the manifest load sheet filed with other flight records. If errors were present in this manifest they could not be confirmed. The present state of the art of digital flight recorders, however, offers a means for determining the flight's actual takeoff gross weight and center of gravity. The STAN system, since it is all solid state and provides digital computation, can provide signals which would be compatible with the flight recorder input requirements so that for each flight this important data could be permanently recorded for possible recovery need.

Since one airline has reportedly suggested that the number of toilet flushings per flight be stored in the recorder system we are sure there is room for TOGW and % MAC too.

Another approach would be for the crew to call in the STAN system weight and balance numbers (on ground frequency radio) just before they begin their takeoff run for recording on the load manifest form in the airline's facility. Then a permanent record of the actual weight and cg would be maintained in case of an accident.

OTHER SOURCES OF WEIGHT AND BALANCE ERRORS

In addition to the errors in actual weight and balance of an aircraft other than passenger and baggage weights consider the following:

a. Human errors in manual calculations.

b. Incorrect basic aircraft starting weight and c.g. due to:
   1. Wrong format being used for particular aircraft (a not uncommon occurrence.)
   2. Weight changes from last official weighing period.

c. Misplaced or mis-weighed cargo.

d. Passenger seating variations from the norm or pre-planned arrangement which are usually based on a normal distribution. Abnormal distribution of passengers effects center of gravity.

e. Fuel guage errors or use of incorrect specific gravity figures for fuel.

f. Accumulations of ice, snow or mud on understructures of aircraft.

g. Absorption of moisture by aircraft soundproofing and seating materials.

h. Weight of wet cargo versus its dry calculated or measured weight.

Availability of IWBS data is most important during the following "normal" operations.

a. Rapid arrival-departure turnarounds of flights

b. Reduced power takeoffs

c. Hot weather or load restricted takeoffs

d. Aft CG loading for reduced fuel consumptions

e. Prolonged fuel burnoff during delayed takeoffs

f. Slush, snow or ice on runways

g. Emergency or war-time operating conditions.

CONCLUSION

In concluding this presentation it can be seen that there is a concentrated effort on the part of several manufacturers to provide safer operation of aircraft by providing useful takeoff data to the flight crew's of their aircraft's weight and balance condition. The present state of the art of IWBS is entirely suitable for most aircraft flying or on the drawing boards but unless it is implemented fully the results can only be termed "spotty". Full fleet utilization of Integral Weight and Balance Systems is a distinct possibility in the future but at present only a relatively small number of aircraft are equipped with STAN or any other similar system. During the next 10 years, however, we foresee that the present 5% outfitted figure will grow considerably so that you, as Air Safety Investigators, should grow acquainted with this new hardware and start looking into the ramifications of the system in your studies of air safety measures. Legislation to mandate the use of such equipment is not imminent and the official view is to leave the matter up to the individual airlines as to whether they wish to equip their aircraft with IWBS and implement their weight control program accordingly. Many progressive airlines are proceeding on this course, fully realizing the initial safety aspects and the long range economic possibilities of the system. Others are taking a shorter view and see only an expenditure without economic payback. Our statement is--one aircraft lost would pay for equipping their entire fleet several times over.

In closing I would like to comment on a recent accident which occurred and which resulted from several factors--any one of which, had it not occurred would have permitted the flight a safe takeoff. Accidents however do not usually occur for one reason alone but as you know, from a series of things. This accident caused over $1 million dollars damage but fortunately no loss of lives. It resulted from the use of a running/turning start which used up 300 feet of runway, the loss of two engines on takeoff run, an unsuccessful abort with overrun of 500 feet off the end of the runway which caused all the damage, and an error in the fueling specific gravity system which resulted in a 6000 pound extra fuel weight than shown on the load sheet. In analysis it was determined that this extra 6000 pounds extended the accelerate/stop point some 200 feet so if we add this to the 300 feet used in the running/turning start we see that the abort could have stopped just at runways end.

We also claim that had the aircraft been equipped with STAN the crew would have seen the 6000 pound weight error and, even though they still chose to proceed with the takeoff they would have been perhaps one split second more alert to possible abort problems than they were under the assumption that all was well in the weight and balance department.

Also they might not have used the running/turning start. After the fact diagnosis of such events is always frustrating but it can bring home the many reasons why weight and balance systems are not a fancy additional frill but a real down to earth necessity if aircraft safety records are to improve. We hope you will see a lot more of them in the next 10 years and beyond.

"HUMAN THREATS TO AIR SAFETY"

IN INTERNATIONAL REVIEW OF CIVIL AIRCRAFT DAMAGED OR DESTROYED BY DELIBERATE DETONATION OF EXPLOSIVES (SABOTAGE) 1946-1972

ERIC NEWTON

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A paper to be presented before the 25th Annual International Air Safety Seminar "Human Threats to Air Safety" Washington DC, October 16-18 - 1972.

1. OBJECT

Let me make it quite clear, right away, that the purpose of this talk is to place before you, put on record, and again emphasise the increasing seriousness of explosive devices being secreted and detonated aboard civil aircraft flying on the worlds air routes. It is certainly not my intention to indicate or suggest how such criminal acts can be perpetrated in 'six easy lessons'. I will however, make reference, by means of a number of colour slides, to the particular type of material evidence found before and after such criminal acts and its forensic significance. This may be of some assistance to aircraft accident investigators and alert security personnel and others whose duty may be to inspect aircraft (security wise) or carry out wreckage analysis in the future.

As there appears to be no immediate remedy to this human problem, attention is again directed to the urgent necessity of continuing precautionary measures and for the continued development and adoption of scientific methods of detection of explosives, some of which are already in operation at a number of airports, on all passengers, their baggage and cargo before it is loaded into the aircraft.

2. BRIEF STATISTICAL REVIEW

So far as it is known, looking over the world picture between 1946 and 1972, 35 aircraft have been damaged or destroyed by the detonation of an explosive device within the aircraft. This figure does not include known hi-jack incidents or shooting down or deliberate blowing up of civil aircraft on the ground in military or para-military activities. Neither does it include unconfirmed cases nor aircraft missing in suspicious circumstances. The figure can be regarded as conservative.

Of this total 16 aircraft were of the piston engined types and 19 were modern turbine engine types.

In all these instances 543 passengers and crew lost their lives and 18 aircraft were totally destroyed.

The diasters occurred in various parts of the world covering some 21 countries and affecting 24 airlines. Some 19 different types of aircraft were involved.

So far as United Kingdom experience is concerned over the last 26 years four British (including Hong Kong) registered aircraft have been damaged or destroyed and 147 people lost their lives.

So far as American registered aircraft are concerned, as I understand it, between 1955 and 1972 there were 7 instances, all in the USA, and 124 passengers and crew lost their lives.

A general review shows that --

Between the ten years, 1946 - 1955, there were 6 explosions, giving an average frequency of 0.6 or less than one per annum, in other words a very rare occurrence.

Over the next ten years however 1956 - 1965 the incidents increased to 9 and between 1966 to the present time 1972 this has increased again to 20 explosions over the last seven years.

Over the last ten years 398 passengers and crew are known to have lost their lives due to detonation of explosives in civil aircraft.

1972 is the worst year on record with 6 cases and 108 people killed in this manner so far within the last 10 months.

3. THE FORM AND SECRETION OF A SABOTAGE DEVICE

There are, of course, many ways in which an aircraft can be sabotaged, just as there are many reasons or motives behind such criminal acts. Experience has shown however, that the most common form employed is an 'explosive device' or that quaint but technically accurate phrase 'an infernal machine'*. Experience has also shown that the saboteur, on occassion, lacks expert aeronautical engineering knowledge of the aircraft hence an unintelligent placing of the 'device'. Consequently, in a number of instances, it has been possible for the aircraft although damaged, to continue to fly and for it to be landed safely at an airfield without loss of life. The type and weight of explosive used has, of course, a bearing upon the incident being survivable or non-survivable.

A number of simply constructed 'home made' yet never the less effective and deceptive infernal machines have also been found during searches. Here lies one of the main problems in security. It is of little use simply to instruct an airline official or a security officer to search for a bomb in an aircraft if he hasn't the faintest idea of what it may look like. He may well have the usual picture in his mind, described in most dictionaries, of a spherical metal object containing explosive with a smouldering fuse sticking out of it! Experience again reveals a never ending variety of shapes, sizes and appearance of infernal machines. To quote just a few known ones - an innocent looking, but modified, commercial catalogue, the popular air travelling cabin bag, a record player, or domestic soap flake box, in fact the explosive, the detonator and time delay, the essential and basic ingredients in every explosive device, can take almost any form or appearance. The saboteur will attempt to camouflage or conceal it. The methods of concealment likewise the motive are infinite and are limited only by the ingenuity of the saboteur.

Some methods of secretion include --

Wrapping in paper, cloth or dirty rags etc.

Placing in passengers baggage, rations or cargo

* Ref Concise Oxford Dictionary - "Apparatus, usually disguised, for producing explosion destruction of life or property"

Placing in containers in every day use such as tins, oil cans, boxes, bottles, toilet compartments, particularly waste towel containers, a known favourite place.

Hiding the device in an easily accessible place such as behind doors, under seats on or in luggage racks, ventilators, small and easily opened hatches such as refuelling panels, landing gear or wing appertures, the list is almost unending when considering a large modern aircraft.

4. MATERIAL EVIDENCE

Normally the circumstantial evidence will be fairly clear that some sort of explosion has occurred. On the other hand, when faced with more than 50 tons of disintegrated and burnt wreckage probably spread for miles and away from civilisation, or salvaged piece meal from the deep sea, the evidence will be anything but clear and the Investigators have their problems. The Investigator must proceed carefully with an open mind before reaching a conclusion that the explosion has no connection with a major malfunction of the aircraft systems or its power plants. For instance, the disintegration of a high speed turbine disc can produce a loud explosive like noise. Shrapnel like pieces of metal can sometimes penetrate the wings or fuselage, with possibly fire, and which in damage effects could be represented as an explosion. There are of course, upon detail examination, considerable differences between this type of "explosion" and the detonation of a high explosive material.

A lightning strike can also, on rare occasions create local explosive like damage, particularly if the aircraft structural electrical bonding is faulty. Normally such lightning strikes will not cause extensive or catastrophic damage but fire and explosion of fuel tanks is a possibility if low flash point fuel is in use and vented near the wing tips, a favoured place for lightning strikes. Supporting evidence of electrical discharge entry or exit, on the aircraft structure should normally be apparent at aircraft extremities.

The material evidence of a deliberately planted and detonated explosive device, if the wreckage is available for inspection, will reveal distinctive characteristics. These will be mainly high velocity penetrations, often very small in size, together with blast and heat characteristics. The detonation of a modern high explosive can create particle velocities of more than 5000 metres per second and deep penetrations of structure or bodies by minute particles can be expected. No failure of any system or power plant in the aircraft can accelerate small particles to such velocities. Scorching, blackening, or high velocity cutting of material or pitting may also be present. Smell also may be a valuable clue as most detonated explosives leave residual fumes or persistent smell sometimes sweet, sometimes bitter or acrid but always distinctive. Normally however, due to time lapse weathering or immersion in water, residual fumes or faint deposits may well disappear but the taking of sample swabs from suspicious surfaces for later chemical analysis is always a wise precaution. The blast location itself, which may be in an area free from any operating mechanism or pressurised system, which could possibly cause such a blast is obviously a pointer in itself. Trajectory plotting by rods, string, or wire can sometimes assist in the location of the origin of detonation. Quite often, by sustained and diligent search for small details, pieces of a detonator or timing device may be found often jammed into a piece of structure, furnishing or a body. Such evidence is vital and often conclusive. Any material, metallic or otherwise, which appears unusual and unidentified with any part of the aircraft should be preserved for further investigation for timing devices are also infinite in design and appearance.

The Flight Data Recorder, if carried, is of course a useful tool for the investigator although not conclusive. It will at least show the circumstances prevailing prior to the disaster which, when analysed can eliminate a number of factors. For instance if all the recorded parameters cease abruptly at one particular point following an apparently normal and smooth flight with the 'g' record diverging suddenly off the plus and minus scales, this could be another lead in support of a violent and sudden disaster. In extremely rare occasions the cockpit voice recorder or R/T tape has also given a direct clue.

5. FRACTURE ANALYSIS

Fractures of metal caused by explosive action are normally different in character to those caused by overstressing or crash impact forces. Shattering of material into very small and numberous fragments and minute high velocity penetrations are characteristics not found in aircraft accident wreckages however fast the aircraft may dive into the ground and explode. Generally speaking the smaller the fragments the higher the velocity of the detonation and is usually indicative of a high explosive being used and also a clue to the focal point or origin of the explosion.

The mode of break up of the aircraft itself and its sequence of failure will usually be very complicated or quite without logic from a normal aerodynamic overstressing point of view.

Inspection of fractures (normally under a microscope) may reveal extensive tensile stretching and rough 'orange peel' surface effect. However the detonation of a modern military type of high explosive can fracture metal with such rapidity that the metal has no time to stretch or deform and fractures in normal ductile metal may appear very short or brittle. Curling, corkscrewing, and saw tooth edges may also be present. However, such fractures in themselves are not conclusive that an explosive is involved, but indicative of a very rapid type of fracture. Fusing of metal, scorching, pitting and blast effect which is often present, is much firmer evidence. Perhaps the most conclusive material evidence to be found on metal specimens is cratering, very often in groups, often minute and numerous. Hot gas erosion is another conclusive explosive clue. Such evidence is often found in material which has been within a few metres of the detonated high explosive and only a high explosive can produce such evidence.

All suspicious fractures and deposits should of course, be preserved and subjected to expert examination under the microscope or scanning electron microscope.

6. CHEMICAL ANALYSIS

Chemical analysis of surface deposits is essential at an early stage, if the type of explosive is to be established. The spectrographic probe can be also very revealing. Analysis may reveal traces of sodium nitrate, carbon, ammonia, mineral jelly, glycerine, and many other chemicals, even sugar. Cabin furnishings particularly cushions may conceal vital evidence and any suspicious material should be X-Rayed and all minute particles collected for microscopic or chemical analysis. Home made explosive mixtures of domestic and freely available materials can also be deadly from explosive or incendiary effect.

7. RADIOGRAPHIC EXAMINATION AND PATHOLOGY (AUTOPSY)

Once the Investigator has obtained material evidence supporting that an explosion has taken place every effort must be made immediately to have the occupants of the aircraft, as many as are available, X-Rayed and for limited pathology, for the extraction of any buried particles, to be carried out. Close collaboration with the medical team or pathologists must be maintained from the start and the purpose for the request fully explained. This often involved co-operation from legal and police authorities and diplomacy and tact is very necessary at this stage. It is preferable for the pathologist to assist or be present during the radiographic examination of the victims. Photography, preferable in colour, is also important. Pathological examination for blast effect of the eardrums, unusual or gross traumatic injuries not normally associated with an aircraft crash impact, examination of skin tissue for hot penetrations, 'peppering' etc. can be of great assistance.

Laboratory examination of extracted fragments by explosive experts in forensic science is essential and should be utilized as soon as possible. When fragments are micro size, and detailed identification essential, quantitative analysis by means of laser micro probe can probe extremely useful.

Consultations with other authorities and scientists in the field of explosives, and forensic investigation of explosions, including leading pathologists is also desirable.

8. LEGAL RESPONSIBILITIES

Finally as sabotage involves a criminal act, all material evidence and the chain of evidence must be preserved. The maximum security should be exercised upon all relevant parts as these may well be required in a Court of Law at a later date.

It follows, of course, that once such a criminal act is confirmed the investigation ceases to be a normal aircraft investigation under the civil aviation accident regulations and becomes a legal investigation into a criminal act. The police authorities must therefore be informed without delay and the relevant evidence presented before them in order that the law of the country involved may then take its course.

9. THE PROBLEM

All this of course, stems from vile human act and is a problem of world wide concern. A problem that is not going to be overcome overnight. Whilst it appears, at the present time, impossible to prevent with absolute certainty a really determined saboteur from carrying out his or her intention, there remains an urgent necessity for continued precautionary measures even if this entails some inconvenience or expense to all concerned.

INTERNATIONAL CIVIL AIRCRAFT - EXPLOSIVE SABOTAGE

PLACE OR COUNTRY OF OCCURRENCE

USA

CANADA

MEXICO

ADEN

ENGLISH CHANNEL (UK)

SOUTH CHINA SEAS (INDONESIA)

FRANCE

VENEZUELA

BOLIVIA

CYPRUS

PHILLIPPINES

COLOMBIA

MEDITERRANEAN OFF RHODES

SWITZERLAND

GERMANY

EGYPT

SPAIN

CZECHOSLOVAKIA

JAMAICA

S. VIETNAM

ITALY

INTERNATIONAL CIVIL AIRCRAFT - EXPLOSIVE SABOTAGE

AIRCRAFT TYPES INVOLVED

DC 3

DC 6B

VICKERS VIKING

L 749 CONSTELLATION

HP HERMES

CONVAIR 240

ARMAGNAC

BOEING 707

C 47

VISCOUNT

BOEING 727

DH COMET

HS 748

CORANADO, CONVAIR 990

CARAVELLE

DC 9

ANTONOV 24

FOKKER FRIENDSHIP 27

CONVAIR 880

FUTURE OF THE AIR SAFETY INVESTIGATOR

CAPTAIN J. D. SMITH

Vice President, Operations and Engineering
United Air Lines, Inc.

I appreciate the invitation to participate in The Society of Air Safety Investigators' Third International Forum. When Anse Tibbs extended this invitation, I mentioned it would not be possible to attend your working sessions, and requested his thoughts on an appropriate subject for discussion. He suggested The Future of Air Safety Investigators. His idea generated a lot of thought and I wish to share some of this review with you.

The aviation community has witnessed many wonderful advances since I first soloed in 1940. When called upon to forecast a Future of Air Safety Investigators, it appears logical to consider that part played by this group in contributing to these improvements. And this is where the review started to become interesting. Having been privileged to participate in some of these advances, the first thought to surface was what is an Air Safety Investigator? Is it a person -- organization -- function -- efforts by an individual or groups of people.

In order to explain the reasons for this question, consider the following: No formal definition of Air Safety Investigator is in the dicitionary. Although "investigator" is defined, Air Safety is not. We can combine definitions of Safety and Investigator to be "An observation or study by close examination and systematic inquiry to protect against failure, breakage or accident." However, this description does not respond to the inquiry, Is an Air Safety Investigator a person -- organization -- function -- efforts by an individual or groups of people? This may sound like a play on words, but let us briefly review some advances of the past.

Standardization of approach lights, visual aids, a single language for air-ground communications, improved weather reporting and air traffic control procedures, required the collective efforts of many interested parties -- none of which involved designated Air Safety Investigators.

Development of the Flight Director and subsequently the Approach Coupler for the most part reflect ingenuity of manufacturers; none of which at the time employed Air Safety Investigators.

Improved flight training techniques, which have contributed to increased levels of flight personnel proficiency are other examples of cooperative efforts by manufacturers, flight personnel, airlines and the Federal Aviation Administration. We are most appreciative of this cooperative effort, and within United Air Lines, we believe we are close to accomplishing our objective of conducting all flight training in simulators.

These are but a few advances realized within the airline side of the aviation community. Examples such as these prompts the inquiry is an Air Safety Investigator an organization -- function -- efforts by an individual or groups of people? Even these limited examples suggest a conclusion, that no individual or single organization by himself or itself can generate the required level of safety necessary for airline operations. Furthermore, safety enhancement is truly a cooperative effort involving many thousands of people, dedicated to prevention of incidents and accidents.

Were the time available, it would be possible to further outline contributions of manufacturers, flight personnel -- both pilots and stewardesses -- mechanics, airport operators, Federal Agencies and airlines designed to prevent incidents or accidents. Many years ago we in the aviation industry lacked the wisdom to effectively define problem areas. And in those days, even if problems were defined, we had difficulty developing solutions or implementing them. The advent of turbojet operations exercised the ingenuity of the industry and as a result we have been able to more effectively prevent problems and accomplish corrective action when necessary.

This brief review is intended to highlight one point, namely Air Safety Investigations are widespread activities involving thousands of people in this industry. We cannot relax our efforts in this activity.

Now what about the future? To begin with, we know new methodologies are coming. We hear about satellites, digital communications, electronic cockpit displays, collision avoidance systems, curvilinear approaches, and 2-segment approaches, to name a few. We hear about the STOL aircraft Supersonic Transport and looking further ahead the Hypersonic Vehicle. In my view, all these advances will become a reality. With this in mind, there is a need to determine how these schemes can best be used and most importantly, how should the new cockpit instrumentation be designed.

I was privileged to participate in a NASA project, initially intended to evaluate the American sponsored SST aircraft, in the ATC environment. This involved using a simulator capable of duplicating anticipated aircraft performance. It was soon established that many additional factors, such as cock-pit instrumentation, aerodynamic stability, noise, fuel flow comparisons, projected aircraft performance and economics, could also be analyzed. This type evaluation is an effective method to determine the best manner for utilizing new schemes. Properly interfacing man and the machine must be assured before final commitments are established. We must also direct the same effort to establish what not to do as well as what to do. Thus, we have another example of effective Air Safety Investigation dedicated to prevention of incidents or accidents.

So far, we have dealt with prevention. Let's consider correction. Correction can be processed in many ways. For example, rapidly monitor the previous days operations, thoroughly analyze incidents and documentation that will quickly highlight undesirable trends. In event of an accident, be prepared to ferret out all the facts and from this data, determine recommendations, if necessary to prevent a recurrence. For the most part, these points are currently in effect.

Generally speaking, our accident investigation procedures in this country do indicate what occurred and how it happened. If one might offer a suggestion, it would be to better determine why it happened. This is dealt with sometimes and while recognizing such a determination may be difficult, the answer to why can be valuable in preventing a recurrence.

Frequently, after an accident, many corrective suggestions come forth, even before all necessary facts become available. If it were possible for those dealing with prevention and correction to have mutual understanding of each others activities, we collectively could better deal with unrealistic suggestions; while at the same time contributing to development of recommendations designed to prevent a recurrence.

You people present tonight are fully familiar with the broad manpower requirements necessary to conduct an accident investigation. Many of these participants are not designated Air Safety Investigators, but yet they do effectively contribute to documentation of facts and development of a probable cause.

So far, you have been exposed to a capsulized version of some factors in considering Anse Tibbs question. Hopefully, they will stimulate some thoughts on your part. These comments reflect observations from an airline pilot's viewpoint. The other users, military, business and general aviation are also involved in the type activity previously mentioned, particularly prevention; however, they are quite capable of presenting their own comments.

By now you undoubtedly have grasped the thought that thousands of people within this industry are dedicated to enhancing safety. Although very few of them have some Safety reference in their job title, as do many of you present tonight, they nonetheless play a very important part in the safety of our passengers and employees. It is because of this activity that I raise the question, What is an Air Safety Investigator? Is it a person -- organization -- function -- efforts by an individual or groups of people?

If one goes back far enough in aviation, it is possible to find evidence that the Air Safety Investigator was an individual, seeking to gain recognition of his thoughts for improving the operation. Such is not the case today.

For many years interested parties have been exchanging views on how to prevent incidents and accidents. Observations associated with incidents and accidents investigations contributed to problem definition.

The cycle we have gone through has been one of problem definition followed by development of solutions. For many years, this concept has been accomplished prior to adoption of new vehicles, hardware, or procedures. Coincidentally with this cycle has been the recognition, that as an industry, we must plan ahead. In our case, we attempt to plan at least 15 years in advance. Much of this planning considers Safety requirements for both ground and flight.

With respect to planning, let us consider the initial training of line flight personnel in the B-747 and DC-10. An FAA approved training program is established prior to delivery of the aircraft. Simulators are delivered prior to receipt of the aircraft. This is an over-simplification of the team effort, however, the end result is that Captains check out in this equipment, including the rating ride in approximately 5½ hours aircraft time. This is 1/3 to 1/4 of the aircraft time required for the earlier turbojet equipment. Advances such as this reflect being able to validate all related parameters of the operation in advance and is the basis for concluding we can effectively apply this technique to the many new schemes being proposed.

We have considered the past, present and future. Note that experiences of the past have served a useful purpose in planning for the future. Nonetheless, we must properly balance our Safety efforts, both flight and ground so as to keep abreast of current, near future and long-term activities. In this regard, we are always interested in suggestions designed to further improve our operation.

An example of this is associated with recommendations released by the National Transportation Safety Board. We review each Board recommendation and log our reaction to each suggestion that may involve airline operations. From 1970 through September 27, 1972, our records reflect 303 NTSB recommendations have been released. We consider 136 applicable to an air carrier. 57 in effect reaffirm our existing procedures; 22 resulted in some action being taken, and many of these actions occurred prior to receipt of the recommendations. 57 are under consideration and a prime reason for this number still under review is that 38 were released this year. During the first nine months of 1972, 169 recommendations were released which exceeds the total of 1970 and 1971 releases. We find these recommendations helpful, however, there are indications that a better understanding with industries' prevention efforts could be of assistance to these advancing recommendations. We would welcome an opportunity to establish such a dialogue.

An analysis of Board recommendations reveals our pre-planning for prevention is advancing. Changes, when necessary, are accomplished and there is a willingness to consider suggestions for enhancing safety of passengers, people on the ground and employees.

Now let us return to Anse Tibbs' question: What is the Future of the Air Safety Investigator? If you can agree an Air Safety Investigator is indeed a person and is part of an organization, and involved with the functions of prevention and correction when necessary and reflects efforts of an individual or groups of people, then the answer can best be summed up as fascinating. Members of SASI and your colleagues should have pride in your safety enhancement efforts to date. As we move forward, our challenge is to generate a team effort that will exercise the world-wide operational, engineering and technological wisdom to their extremes and thus realize a global air transportation which will safely and efficiently serve all mankind.

Psychosocial Reconstruction Inventory: A Postdictal Instrument in Aircraft Accident Investigation

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A new approach to the investigation of aviation accidents has recently been initiated, utilizing a follow-on to the psychological autopsy. This approach, the psychosocial reconstruction inventory, enables the development of a dynamic, retrospective portrait of the pilot-in-command subsequent to an accident. Twelve fatal general aviation accidents were studied in this way in 1971. When routine accident investigation data are supplemented by a psychosocial or "lifestyle" reconstruction, a much deeper understanding of the cause of the accident often emerges. In addition to the traditional detailed explanation of what happened, it is often possible to determine why the pilot-in-command behaved in a fashion to produce the accident. By increasing pilot insight into the role of emotions and situational stress in accident causation, more effective accident prevention programs should result.

AIRCRAFT OPERATIONS at the 335 FAA-operated Traffic Control Towers numbered 55,280,498 during calendar year 1970, a doubling from the 1960 figure.[1] Of the above, 22,362,196 of the operations were conducted by general aviation. General aviation experienced 626 fatal accidents involving 1,273 fatalities in 1970 in their portion of the above operations, plus their operations to and from those of the 10,847 airports which did not have FAA control towers. FAA Office of Aviation Medicine accident records describe the circumstances surrounding each crash. A majority of these documentations, however, fail to indicate "why" the event occurred. Many of these incidents, perhaps a majority, resulted from intentional or subintentional pilot error.

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Relatively scant literature exists concerning studies of the accident-facilitating behavior of pilots involved in aircraft crashes. Therefore, the senior author (Dr. Yanowitch) developed an instrument based on the psychological autopsy and modified to "postdict" the behavior of the victim. This approach delineates the etiological factors underlying the accident by means of the psychosocial reconstruction inventory.

It is recognized that there is some degree of the unexpected in all occurrences and, therefore, almost all events can be studied with respect to "accidental" qualities. Most events, however, exhibit predictable qualities which comprise the prime etiological basis for the circumstances.

It is a common observation that persons often experience preconsciously determined "accidents" (loss of articles, forgetting appointments, and other similar occurrences). A great deal can be learned about accidental phenomena by studying all accidents rather than only those that result in injury or fatality; however, for practical reasons, this paper is primarily concerned with "postdictal" studies of fatal aircraft accidents. The method under discussion is especially relevant to accident prevention since it extracts information which will be employed to impart insight for individual pilots concerning specific periods of their lives when they are ill-advised to pilot aircraft. High risk factors appear to prevail under given circumstances of personal life.

In view of the foregoing, the development of the psychosocial reconstruction inventory involves the collection of psychological data concerning the developmental behavior and functioning of the deceased from birth to the time of traumatic death, the latter possibly self-determined. Information is particularly significant concerning the period of time immediately preceding the fatal episode.

Historically it is noted that the psychological autopsy originated in 1955 at the Suicide Prevention Center in Los Angeles under the guidance of Dr. Edwin S. Shneidman and Dr. Norman L. Farberow, in liaison with Dr. T. Curphy, the Los Angeles County Coroner.[2,3,4] Vital services and research functions were carried out through the coroner's office in the investigation of cases of equivocal deaths (i.e., in which the mode of death was uncertain, possibly suicidal). The staff members investigated these cases by obtaining a psychological picture of the deceased through interviews with survivors. The coroner found that the addition of this information to that data available through routine investigation resulted in a more meaningful certification of the mode of death. It was also discovered that mourners were often assisted in adjusting to their period of grief through the interviews associated with the psychological autopsy.

PROCEDURE

A prescribed procedure for developing a lifestyle "postdictal" profile was applied in 1971 to the pilots of more than a dozen fatal general aviation accidents. Each profile consists of an inventory of personal information derived from interviews of family members and close associates of the deceased by a psychiatrist; individuals chosen for interview were those who might significantly affect the behavior of the subject and those in a position to objectively observe it. The derived information presents a history of the psychosocial development of the individual and any pre-accident deterioration. Essentially, the inventory consists of the key elements in an individual's life insofar as they may be determined retrospectively. It may be conducted by any professional or paraprofessional well acquainted with the psychodynamics of behavior.

Illustratively, the inventory may be outlined as follows:

I. Informants
- A. Spouse (including previous spouses, fiance/fiancee if applicable)
- B. Parents
- C. Siblings
- D. Children (mature)
- E. Airport personnel
- F. Close friends
- G. Business associates
- H. Flying associates (including instructors)

II. Areas of Dynamic Influence
- A. Familial constellation
- B. Procreational family
- C. Economic, social and educational history
- D. Physical and mental health

III. Pre-Accident Influences and Behavior
- A. Influences (Any psychosocial deterioration is noted, including development of depressive episodes, occurrence of guilt feelings, lack of self-esteem or sense of identity; likewise such situations as economic reverses, loss of loved ones or marital discord.)
- B. Behavior (Specific behavior prior to the final flight may be very instructive, particularly if there is obvious variation from established behavior patterns. A good example is adherence to pre-flight procedures.)

Synthesis of the above information yields a life-style picture, touching on basic beliefs, attitudes, aptitudes, experiences and accomplishments of the victim. General behavioral characteristics are noted and interpreted in dynamic context. Relatively recent changes in the individual's personality may reflect an increasing difficulty with emotional control and coping mechanisms, involving status of relationships with family and friends, perhaps a deterioration culminating in the fatal crash. Thus, a coherent summary personality profile relative to flight activities and the fatal flight is sought, with the ultimate goal of prevention.

To date the psychosocial reconstruction inventory has been applied to fatal aircraft accidents when the Regional Flight Surgeon of the involved FAA region has requested additional information.

Three examples drawn from the preliminary case files are provided below:

1. *Case Number 70-4213:* The 52-year-old male subject crashed in his light twin-engine aircraft four minutes after normal take-off. The aircraft struck the ground nose-down at a 45° angle and was completely demolished. The physical autopsy disclosed no alcohol, drugs or CO factors in the "accident." No mechanical failure was found.

The psychosocial reconstruction inventory disclosed the following information pertaining to recent problems facing the subject:

A. A criminal charge of arson was pending against the victim.
B. A civil suit was being considered against him by an insurance company.
C. The U.S. Internal Revenue Service was claiming a large arrears in his income taxes.
D. The victim's wife was suffering from advanced cancer.
E. A pending separation from the wife was becoming more pressing.
F. The completion of certain projects placed his future occupational status in jeopardy.
G. A recent inability to keep up payments on his aircraft threatened its continued availability.
H. An inability to keep up repairs on his aircraft jeopardized its airworthiness.
I. A self-need to undertake "masculine" activities became increasingly difficult to fulfill as the aging process continued.
J. A recent suicide attempt by his wife was extremely upsetting.

In context, the above items suggest the life-style of a man who never developed beyond the oedipal stage and who had a deep need to assert his masculinity in overt manners such as hunting, game fishing, scuba diving and flying. The strong self-imposed pressures to accomplish these manly activities derived from his lack of identity. The over-all anxiety led the subject to attempt to be everything-to-everybody-at-all-times in order to make himself acceptable to all. His final behavior appears to be a regression to the infantile omnipotent state in an effort to control the uncontrollable events which were causing his progressive deterioration. This information indicates that the probable mode of death was intentional suicide.

2. *Case Number 71-2433:* The 47-year-old male subject crashed his light twin-engine aircraft on a clear night, killing himself and his female companion. It was found that he had been heavily consuming alcohol in the period immediately prior to the crash, and that the bartender of the last bar where the pilot and passenger had imbibed together had called the airport and advised that they be prevented from initiating flight. Later that night a tower controller recorded communications demonstrating that the pilot had slurred speech, geographic disorientation in spite of good weather, and increasing confusion

in the operation of the light twin-engine aircraft. The aircraft crashed when it ran out of fuel following improper navigation by the pilot.

The psychosocial reconstruction inventory indicated that the subject was characterized by an impulsive personality, and maintained his emotional equilibrium by violently acting out against those who "stepped on his toes." Other significant factors indicate that his behavior was the product of specific family relationships in his early history. The subject and his wife had recently separated and he had suffered the additional stress of being arrested as an "ordinary criminal" in the presence of his children, a circumstance based upon his violation of visitation rights. The victim did not trust banks and routinely carried huge sums of cash, as was the case on his final flight.

Although the subject was inebriated when he took off on his final flight, his wife noted that this was not a previous practice of his. She did state that she had known him to take a jigger of scotch on some occasions immediately before flying.

Based upon the collected information, it is construed that the motivation for attempting the final flight was supplied by the sociopathic personality of the female companion. Briefly, she had made several suicide gestures and attempts in the recent past and actually had been released from a mental institution on the day of the fatal crash. The psychosocial reconstruction inventory indicates that she was able to influence the subject's behavior as a pilot to the extent that she caused her own death and that of the pilot, an unusual case of suicide by "homicide:" she the instigator, he the instrument, both the victims.

3. *Case Number 102-AM 120:* The 51-year-old, highly educated male subject departed in his single-engine aircraft, ostensibly for a specific destination near a scientific meeting site. The aircraft was found in a bay, far off course, and the subject's body was found floating nearby. This type of occurrence is traditionally reported as a water impact. However, the subject was in a "wet-suit" of the "frogman" type and his clothes were in a waterproof bag tied to him.

The psychosocial reconstruction inventory revealed that the victim, who held a Ph.D. in psychology, had been raised by a compulsive, dominant, frequently absent father within a high socio-economic setting. A reconstruction of the situation revealed that the lack of a mother's hand and the absence of sibling interplay had permitted the victim to develop fantasies of being totally self-sufficient. This self-sufficiency served as a protective screen in that it indicated that the subject controlled his destiny and environment with little input from others, precluding the possibility of failure in accomplishing the tasks he set for himself. This led to compulsive behavior, and the particular attitude that the subject must be totally "in charge."

The information developed indicated that the subject was highly suggestible (this may have been autosuggestibility) and that he had personal desires to assume the identity of a fictitious person. He was confronted with an essentially unsolvable dilemma concerning his role in life and "took flight" toward an assumed identity in an attempt to escape a personal life he could no longer tolerate. In addition, the pressure derived from his socio-economic background and his inability to control his wife's probable mental deterioration appear to have triggered the necessity of separating from the disturbing domestic influence. The subject determined that the manner of separation could not be of the usual form.

The subject chose a method of separation which evidently was disturbing in that the plan consisted of a practiced deceit which he could not well tolerate by virtue of his psychodynamic make-up, since the approach consisted of frank hypocrisy. As the subject could not tolerate deceit and hypocrisy, unconscious machinations forced the inclusion in his grand plan of an event of such great challenge and requiring such skill that if the challenge were not properly met or the skill were lacking, the price would be loss of his life. If successful, the plan would prove to the subject that he was in complete control of his destiny and he could carry on in a totally different identity. He successfully ditched the aircraft but subsequently drowned before reaching shore in his wetsuit. However, this variable was deliberately written into his life script and the mode of death, based upon the available life history, is a probably subintentional suicide. The degree of risk in his plan was unnecessarily great to accomplish his goal.

DISCUSSION

The reconstruction of the psychosocial process leading to an accident requires data collection in addition to that routinely collected by the FAA, NTSB and other authorities. The routine information is often sparse, especially when a tense emotional state existed prior to the accident between the victim and those close to him. At times the emotional reaction of the lay investigator to his own feeling of concern for the victim's family can interfere with an objective judgment about the circumstances that contributed to or provoked the accident. Too frequently an official investigation amounts to a description of what happened and avoids that body of information which indicates why. Upon collection of psychosocial background information, a case conference and investigative review should become important elements in getting to the "why" of an accident.

It is noted that difficulty in collecting data arises from deliberate or unintentional distortions of information recalled by informants. Evasion may at times be encountered as may denial, even direct suppression of evidence. In some cases suicide notes may be deliberately destroyed by survivors after a fatal crash.

It may be necessary to explain to informants that self-destructive tendencies do develop in responsible, religious, or "successful" persons, and the fact that the deceased may have made plans for the next day or week is not sufficient reason to rule out a simultaneous preccupation with suicide or a suicide plan. In this connection it has been found that the interview exchange often reduces grief in the survivors and makes it easier for them to accept the death of the victim. These interviews may thus be not only purely investigative but therapeutic as well.

Since some accidents involve frankly suicidal or "subintentionally" suicidal psychodynamic mechanisms, attention must be given these possibilities in assessing the preventability of air crashes. Suicidal actions take a great variety of forms, and the reasons, motives, and psychological intentions of suicidal persons are quite complex. Some of the most prominent motivational reasoning of suicidal persons involves (1) a wish for surcease, escape or rest, (2) a feeling of anger, rage, or revenge, (3) notions of guilt, shame, or atonement, and (4) wishes to be rescued, reborn, or to "begin again." Suicidal actions also contain important communications and appeal elements which are too frequently ignored until it is too late. It has been found that destructive ideas or impulses ordinarily are well-controlled and most unconscious. However, these impulses can be brought to the fore and released under influences of mental stress, physical exhaustion, frustration, alcohol, drugs, and other tangible or intangible agents.

An important additional consideration with respect to suicidal activity is that the continuum of behavior in suicide ranges from detailed planning with direct consummation of death to that characterized by a confused approach involving carelessness and self-negligence (intentional or subintentional). The present legal classification of death into "natural," "accidental," "suicidal," and "homicidal" categories is derived from ancient tradition and later legal procedures. The social benefits of this classification are in assignation of responsibility for the death in the moral or the legal sense.

The individual, himself, often plays the deciding role in causing his own demise, and this self-destructive effort may result in death in many circumstances that ordinarily are not considered suicidal.

The "psychological autopsy" seeks to clarify the immediate psychodynamic processes leading to death. It is accomplished by interviewing those who knew the deceased, including close family members, business associates, friends and neighbors. The "psychosocial reconstruction inventory" is an extension of this approach, and seeks to collect life information derived throughout the life span of the deceased, even as far back as his prenatal experience.

In relation to the above it is stressed that the airplane, as with other "human-guided" transportation vehicles, is often symbolically much more than a traveling machine that takes the driver from A to B. It actually represents an extension of the individual and to a greater or lesser extent enhances the self-concept of the pilot. Consequently, considerations, especially emotional factors, have a very significant part in determining safe flight activities on behalf of a given pilot. The changing interplay between rationality and emotionality determines the outcome of a specific flight. The changing characteristics of the pilot with age and with his life-experience must be comprehended by the pilot, assisted through safety educational activities.

CONCLUSIONS

Despite concentrated airman proficiency programs, periodically strengthened FAA enforcement activities and broadened general aviation safety education activities, a seemingly irreducible number of fatal general aviation accidents occur each year. In these cases the pilot, not the aircraft, is the predominant causal factor.[5] Current routine accident investigation procedures do not elicit the accident-related psychosocial factors which are the basic determinants of a significant proportion of today's accidents. The psychosocial reconstruction inventory has demonstrated considerable promise in delineating the psychodynamic factors which led to the pilot behavior causing an accident. When a sufficient number of case histories and the associated psychodynamics are catalogued and made available to pilots in general, many pilots, with the exception of those of the most marked psychosocial deterioration, will, it is hoped, have sufficient self-insight through "pre-programming" to forestall undertaking pilot-in-command duties during those periods when emotional factors tend to override reason.

It is concluded that if efforts are made to extend the psychosocial reconstruction inventory to a significant number of general aviation accidents, the derived information will yield a new and clearer understanding of the casual aspects of these accidents and will result in the addition of this new dimension to aviation safety programs of the future.

REFERENCES

1. Federal Aviation Administration: *FAA Air Traffic Activity—Calendar Year 1970*, Department of Transportation, Washington, D.C., February 1971, pp 23-25.
2. Shneidman, E. S.: Suicide, sleep and death: some possible interrelations among cessation, interruption, and continuation phenomena. *Jour. of Consult. Psychol.*, 28:95-106, 1964.
3. Farberow, N. L., and E. S. Shneidman (Eds): *The Cry for Help*. McGraw Hill, New York, 1961.
4. Curphey, T. J.: The forensic pathologist and the multidisciplinary approach to death. *In* E. S. Shneidman (Ed.), *Essays in Self-Destruction*, Science House, New York, 1967.
5. Mohler, S. R.: The predominant causes of crashes and recommended therapy. Office of Aviation Medicine Report AM 66-8, Federal Aviation Agency, Washington, D.C., April 1966.

ABSTRACT

BEHAVIORAL SCIENCES AND ACCIDENT INVESTIGATION

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Behavioral scientists working in the field of safety research must base their recommendations for accident prevention programs upon data supplied by the accident investigator. The validity of the recommendations made depend upon the validity of the data provided. It is the purpose of this paper to provide the accident investigator with some guidelines as to the kinds of information which would be of benefit to the behavioral researcher.

For example, the term "pilot error" is challenged as being a useful causal concept in safety research. The concept of causality is foreign to a scientist who is trained to be aware of the pitfalls of assigning causes to events. Whereas the legal expert may be required to affix blame, the behavioral researcher wishes only to determine how similar accidents can be prevented in the future. All too frequently an accident investigation attributes the cause of an accident to pilot error with no further explanation than such statements as "selected wrong course of action" or "lack of judgement". Pilot error should be regarded as a result of precipitating factors rather than a cause of accidents. In other words, pilot error occurs as the culmination of a number of adverse events. It is proposed that in-depth pilot background surveys be done on such accidents to uncover information on such precipitating factors.

This information includes data on such factors as human engineering problems, factors due to inadequate training or mishaps associated with personal psychological stresses. Human engineering deficiencies may show up in aircraft accidents as cockpit design problems (design-induced pilot error), aircrew task oversaturation, or inadvertent operation. Examples of these are presented.

Mishaps in which inadequate training is involved may be revealed through problems with negative transfer of training in inadequate transitioning from one aircraft to another or through habit interference problems.

A final area of investigation, perhaps the most important, is one that is frequently overlooked in accident investigation. This is the effect of personal psychological stresses on the crewmembers behavior at the time of the accident. Thorough investigations into these matters require extra effort, are time consuming and sometimes personally distasteful to investigators who must probe delicate areas of personal factors with bereaved loved ones or close friends after an accidental death has occurred.

Willard Kerr's adjustment-stress theory is discussed. According to this theory the majority of accidental behavior can be explained by stresses which cause a man to perform in such a manner as to increase his accident liability. These stresses may be produced internally or externally and are difficult to predict because of their transitory nature.

Another theory recently postulated by Holmes is that life changes such as illnesses in the family, deaths, marriages, births, divorces, job changes and even vacations produce stresses which can adversely affect a person's health. A scale is used to determine the severity of these life changes and their interactions in bringing about stresses which lead to diseases and mental depression. Holmes' theory can potentially be extended to accident behavior. The implications of investigating such life changes and assessing their possible impact upon the mishap is discussed.

SEMINAR SUMMATION

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Once again I have the privilege of being the last speaker at a SASI Seminar, a privilege in more than one sense because nobody has the opportunity to question any points of contention which I might raise.

I have no intention of re-iterating the content of all the subjects on the programme but there are some particular aspects which I wish to cover. It is evident that we would all like to see the day when there is no future for aircraft accident investigators. However, right now, and no doubt for a long time to come, there is a future and this is where I become confused in my task of presenting a summation of this Seminar.

I am not confused with the individual presentations but I see this Seminar as covering three major areas, maybe four.

During the Second Annual Seminar those present were asked a number of questions concerning the type of presentation they would prefer in the future. It is apparent that the Programme Committee has taken cognizance of the replies and has succeeded in finding subjects and speakers to alert and educate accident investigators to techniques and problems which can be encountered. I for one am in favour of this approach and it certainly is in accord with the theme of The Future For Aircraft Accident Investigators.

The second major area of this Seminar involved questions primarily related to "future aircraft accident investigations" and some of the areas requiring future work. Captain J. R. McDonald (ALPA) spelt these out as did a number of subsequent speakers. As a matter of interest action is proceeding on some of these aspects at an international level. For instance the matter of flight data recorders and cockpit voice recorders was raised, in particular the need for expanded parameters and the need for protection of the evidence therein at both national and international levels. A few months ago at an ICAO world-wide meeting (7th Air Navigation Conference) States agreed on specifications for expanded parameters and these will become effective in the near future. Arrangements are currently in hand for a meeting in about eighteen months time in which one major subject is expected to be the retrieval, retention, and use of flight data recorder and cockpit voice recorder information.

Underwater Aircraft Locator Beacon - the need for international agreement concerning the carriage of such equipment and technical specifications were discussed at a recent world-wide meeting. Decisions were deferred at an international level because it was considered that such equipment was still in the developmental stage, but the subject will be reconsidered at a later date.

Both Dr. Stan Mohler and Mr. Eric Newton raised the aspect of the significance of medical autopsies as a tool in aircraft accident investigation. Amendments to Annex 13 Aircraft Accident Inquiry became effective in July 1972 which were directed towards giving greater emphasis to this subject and a completely new Chapter concerning the medical input has recently been included in the ICAO Manual of Aircraft Accident Investigation. A world-wide meeting in the near future is expected to derive a method of obtaining a better international gathering of injury and survival data in order that more effective surveys of crashworthiness can be undertaken.

It is the third major area of this Seminar, however, on which I intend to dwell for a few minutes. In his presentation Mr. Jerry Andrews defined an accident investigator as a gatherer of facts. Taking the title, this Seminar then becomes "a review of the future for those who gather facts" and, with hindsight, I believe that we have inadvertently severely restricted the input into the programme of the meeting.

The name of the game is accident prevention. It was first raised by Governor John H. Reed, followed up by Mr. George S. Moore, mentioned by some speakers, and highlighted by Captain J. D. Smith. But we haven't really discussed it.

Accident Investigation is merely one tool - we have discussed investigation and done it well. Another tool is the analysis of the information received from many accidents. Dr. Kraft gave us an example of how such analysis can lead to specialized research. At the NTSB you saw that they now have improved capability to conduct analyses. ICAO is currently finalizing the first international steps in this direction and arrangements are already in hand for the next stage to be undertaken during 1973. Additionally, it is interesting to note the number of speakers who referred to aircraft incidents, their value in the assessment of safety programmes, and the difficulty of obtaining such reports. International specifications for the exchange of such information have now been prepared and, hopefully, they will become effective during 1973.

Improvement in the accident rate is not "the impossible dream". The evidence that it can be done is with us. The Boeing 747 has now been in airline operation for some time without being involved in a major accident and I believe that the same will be true of its competitors, the DC-10 and L1011. Why? How? I suspect that for the first time the managers of the airline purse-strings became genuinely afraid when confronted with the fact that one accident could involve financial ruin. I suspect that for the first time top-level management gave equal priority to operational and economical factors.

Whatever the reason, for the first time in many years "operational management" has been given the opportunity to engage in training and educational programmes all of which are aimed at Accident Prevention. As I said - the evidence is there - they have been successful.

Additionally it is significant that similar programmes in those airlines which have only recently changed to new aircraft equipment have also been successful. I note that Mr. George S. Moore outlined an FAA programme which appears to be designed along similar lines - it is my personal view that such a programme should meet with success.

I'm disappointed that we didn't delve deeper into the area of accident prevention.

The fourth major area of this Seminar we hardly covered. Two examples come to mind. Mr. Hawkins spoke about STAN, a device which could possibly prevent an accident occurring. Taking one area of Dr. Kraft's presentation, he demonstrated an inadequacy of the human being - an inadequacy over which a pilot has no control. Answers to Dr. Kraft's problem are available: they involve placement of light patterns in the approach area, air traffic control procedures, landing aids, and cockpit procedures. Implementation may involve a trade-off against economics but the technical answers are there.

The question I leave you with is this and, essentially the same question was posed by Captain J. D. Smith. To me, the significant words in the title SASI are Society of Air Safety - isn't it time that the knowledge present in this body of expertise became actively engaged in accident prevention. In addition to the passive role we now play by conducting Seminars such as we are now attending, isn't it time that people such as ourselves were heard and pressed for changes in systems, procedures, facilities etc. which our experience indicates are accident prone.

I don't know of any other organization which contains such expertise. I am sure that if your answer is "yes, it is time" then SASI would gain the international support for which it has been striving over the past years. This is where I see the future for SASI and the future for aircraft accident investigators.