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FORECAST OF AIR TRANSPORT SAFETY PROBLEMS 1970-1980

by

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FOREWORD

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It is most important for air transportation to improve an already good safety record. ICAO reports that the accident rate hovers at about 3 fatal passenger accidents per million revenue hours, over the past five years. Fatal accidents per million stages or flights are parallel to hours at about 3-1/2 fatal passenger accidents per million revenue aircraft landings. The trend is favorable. But the ten million hours flown in scheduled air transport operations in 1967 is expected to more than triple during the period 1970 - 1980. Instead of almost 30 fatal air transport accidents per year which now occurs, there could be about 100 if the present accident rate continued. Furthermore, this period will witness the introduction of new types of aircraft such as the SST, the Jumbo Jet and V/STOL which are likely to create new safety problems during their introductory period.

Therefore when asked to prepare a paper on Safety in Air Transportation for this Congress, I requested permission to focus on the problems of the next decade. To do this I sought the help of specialists in 15 pertinent fields of government regulations, special action items, airline engineering, research, air traffic control, weather, all weather landing, reliability, training, systems, computers, the cockpit, human factors, medical affairs, statistics. This still leaves much to be covered such as accident investigation, crash survival and ditching, sabotage, and exchange of accident prevention information. Some of these are touched upon by several authors. I have added a discussion on accident investigation and the contributions of space flight to safety.

Improvements in aviation safety materialize slowly. The inertia is understandable if not excusable. The paper on "Aviation Weather Service and Requirements" by Newton Lieurance and on "Airline Engineering" by Jack Dyment refer to financial constraints on safety development. But political obstructions, sociological demands, competitive factors, the need to prove the reliability and value of new techniques and the time required to obtain agreement of many interests add to the inhibiting influences. Therefore today's safety problems will extend well into the next decade. We can continue to expect for instance that about 50% of the fatal accidents will occur on the approach to a landing even though techniques exist to alleviate that problem. These are indicated in Captain William Moss's paper on "Action Items" while Mr. George Litchford urges caution in his paper on "The All Weather Landing Problem." Walter Tye raises the problem of reliability of the coming gadgetry and is concerned whether pilots will be able to retain skills which will be used infrequently because of automation. E. W. Pike also includes the landing problems in his discussion of a proposed ATC system.

Consider the problem of the learning curve which has afflicted the introduction of new types of aircraft. Obviously the unfavorable aspects of the learning curve can be overcome to a considerable degree by improvement in training. The use of in-flight multi-channel data systems to monitor subsystem performance and to record the departures from approved operating practices before they result in accidents should be very valuable in reducing accident rates. These three topics are included in U. J. Kampsen's paper on "Training" and again by Jack Dyment on "Airline Engineering."

The great need for prompt and more effective exchange of accident prevention information is not covered in these presentations. The obstacles to the exchange of information on accidents and incidents have been thoroughly explored in papers over a period of years. The problems and possible solutions are well stated in an article entitled "Safex" by Harold Caplan in the June 9, 1968, issue of the "Aeroplane." Its significance is strongly supported in these series of papers by Mr. Robert Dressler's discussion of "Statistics." Some segments of industry already realize that the exchange of information to prevent accidents is more important than the factors which inhibit exchange of information such as exposure to legal liability, diminished pride, or management/employee relations.

Some overlap exists in these presentations. For example, Capt. Robert Buck in his paper on "The Cockpit" agrees with Dyment on the desirability of direct lift control and on the need to find a solution to the fire problem. Dr. McFarland in his presentation on "Human Factors" supports Jack Dyment on the need to alleviate mental stress but also says the tendency to error can be increased by mental "underloading." McFarland agrees with Dyment on the need for slower approach speeds but expresses it differently, "Distance travelled in relation to human response times must be kept within known limitations." It remains for Jack Enders in his paper on "Research for Air Safety" to introduce a new subject: the safety aspects of the rapidly growing "miniliner" (the so-called third level airliner). Mr. Lieurance outlines the special needs for weather services for the short haul aircraft. Another new problem is mentioned in the paper on "Medical Aspects of Commercial Flight" (by Dr. Ludwig Lederer, Dr. Andre Allard and Dr. Geoffrey Bennett), namely the increased possibility of unscheduled landings for medical reasons because of much larger passenger loads.

The growth in aviation activity will place tremendous pressures on governmental regulatory agencies. Responsibility for the certification of airworthiness of private aircraft in the United States has been delegated to the manufacturers. The paper by Mr. D. D. Thomas on "Orientation of a Government Regulatory and Enforcement Agency for the Decade 1970-80" implies that the Federal Aviation Administration plans to delegate its safety responsibility to the manufacturers and operators of transport aircraft, but to be monitored by government. Both Mr. Thomas and Mr. Leroy Simpson ("The Digital Computer for 1970-80 Air Safety") pointed to the use of the computer for monitoring operations. Perhaps other governments will need to follow this procedure.

The airline industry of the 1970-1980's will not be able to afford the luxury of prolonged ignorance as to the cause of an accident when large and costly aircraft are involved more frequently than at present. Public apprehension must be more quickly countered than in the past. Increased complexity of aircraft will not ease the determination of probable causes.

The expected growth in air traffic is likely to produce more accidents even if the rate improves. However, the number of available government accident investigators is not likely to increase proportionately because of budget considerations. This may call for a reduction in workload on accident investigators by reclassification of the types of accidents to be investigated. Perhaps some investigative responsibilities will be delegated to industry or other agencies in which the public could place its trust, but monitored by government.

Sophisticated flight recorders, crash and fire proofed, or telemetry, can contribute enormously to the rapid solving of the accident investigation problem. Objections are well known, what will be done with the vast amount of data these devices can collect? Solutions are well known - discard that which has no value. Successful telemetry techniques used in the investigation of in flight incidents in space operations will be discussed later.

There are other ways to expedite accident investigation. Thousands of man hours are used in putting together fractured and scattered parts. This time could be reduced by painting the interiors of the aircraft frame in different colors, an old suggestion. Even jig saw puzzles have color to help put them together! Obstacles to performing autopsies should be overcome. Then steps should be taken to expedite this and other aspects of investigation by fast and easy access to laboratory facilities and experts. Investigative equipment designed to be carried by aircraft should be available to go anywhere promptly. Computers and simulators might be more extensively used for accident investigation. Incidents which accumulate by the hundreds or thousands over the life of an aircraft could be programmed for use when an accident occurred. This might preferably be done by each manufacturer, following a universally adopted programming code, with the support of governments or ICAO. Theories or postulates as to the cause of an accident, based on the collected incidents, could then be put into a simulator for trial.

It would be very desirable to make a time study of accident investigation. Probably the period of gestation following the accumulation of all the evidence requires most of the time. In some accidents it might be research work that takes the most time. The gestation period prolonged by the uncertainties of the evidence and combinations of variables which led to the accident could be reduced very greatly by sophisticated flight recorders or by telemetry. A good example is the DC 8 fatal training accident involving a two-engine-out approach. The on-board sophisticated flight recorder enabled the probable cause to be determined in a few weeks whereas without sophisticated flight recorders the average time to arrive at a probable cause in fatal airline accidents is 11 months in the United States.

Contribution of Space Technology to Aviation Safety

Space technology includes satellites and missiles as well as spacecraft intended for scientific missions. Current contributions of space satellites to safety are obvious: improved weather information, navigational fixes and reliable communications; ultimately traffic control and the location of lost aircraft will be possible. Inertial navigation developed for space is in operation. Guidance and control equipment recovered from the Gemini 11 spacecraft is being flight tested aboard a helicopter by NASA. This includes the computer which controlled the Gemini 11 descent, the inertial navigation system and the power supply. The purpose of this test is to help develop the system performance requirements for automatic landings for future VTOL and STOL aircraft.

Development in the monitoring of the physical condition of the astronauts will lead to very simple unobtrusive devices not attached to the body which will warn the pilot of fatigue or inattention as well as impending illness or perhaps a heart attack.

NASA research to reduce fire hazards is being applied to aircraft. Wee TV for inspection is another of many applications of space to aircraft.

The new discipline of systems safety introduced by the Department of Defense for the Boeing Minute Man Missile and then adopted for the Lockheed C-5A and now by NASA is also a contribution by space technology to the state of the safety art. General von Kann discusses this in the paper on "A Systems Approach to Safety."

The use of rockets to improve take off is an old technique but current rocket developments will find their way into hypersonic aircraft of the 1980's and perhaps into attitude control of VTOLs of the 1970's.

The research being conducted to provide better product integrity of spacecraft by management techniques, manufacturing methods, and new inspection procedures should benefit not only aviation safety but all of industry.

Space offers other opportunities to air transportation. The association of high vacuum with zero gravity could be used to manufacture materials that would be impossible on earth. For example foamed steel may be made which has one tenth the weight of the usual steel of equal strength. The uniform dispersion of gas to create the foam is made possible by a zero gravity vacuum environment. Variable density turbine blades may also be feasible. Very accurate spheres for ball bearings with hollow interior to reduce weight are possible. Material in a liquid state forms a perfect sphere in zero g environment; gas would be injected to form the hollow interior.

The extensive use of telemetry and the associated world wide network of tracking stations offer a tremendous potential for monitoring the operational performance of high speed long range aircraft. In the event of an accident it will provide data to determine rapidly the probable causes. As I mentioned before, telemetered data could be limited to that which exceeds "red line" values and to other anomalies. The economic advantage of shortening the accident investigation, reducing guesswork and expensive accident research to effect a fix can be enormous. The costs of telemetry must be balanced against the enormous costs incurred when an airplane model has to be grounded or its performance curtailed pending determination of the cause of an accident.

NASA techniques for the investigation of anomalies and structural failures that have occurred in space operations should be of value in air transportation. The flight of Apollo 6 of April 4, 1968, had two engines shut down in flight; another failed to restart; unacceptable longitudinal vibration took place; a panel of metal measuring about 36 square feet was lost from the lunar excursion module adapter.

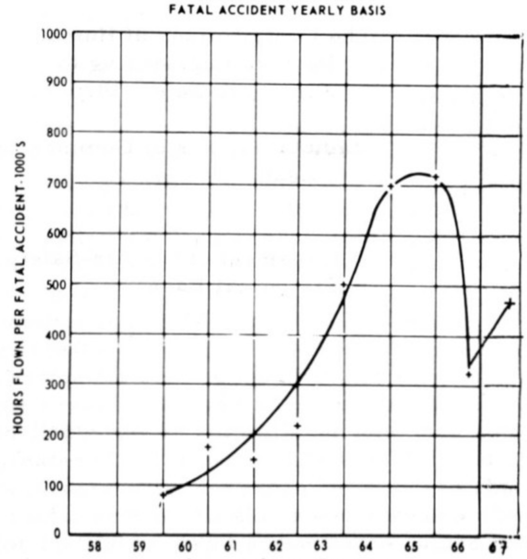
The engine failures were caused by the total rupture of a flexible propellent connection and the partial failure of another. An oversight in the installation and testing of a section of electrical wiring caused one of the engines to shut down. The loss of the metal panel resulted from a unique combination of vertical and longitudinal oscillation.

This occurred hundreds of miles in space. The parts were never seen or examined again. Yet the reasons for their failures were determined, verified and fixes tested within eight weeks. The basic data was obtained by telemetry from temperature probes and accelerometers. The techniques used for this analysis will be published by NASA. Hopefully they will arouse interest to accelerate the determination of causes of large air transport accidents of the future.

Even with these anomalies the vehicle went into an orbit for which there was a contingency plan of operation. The astronauts, had they been on board, could have completed the mission safely. This is a remarkable confirmation of the nature of the engineering effort for space operations that can be useful to aviation.

It has been my privilege to observe the safety of air transportation improve over 500 fold in forty years, as measured by the pilot fatality record. Many suggestions for further improvements are described in these papers. Industry hopefully will find ways to accelerate implementation before public sentiment compels it to do so.

TOTAL JET HOURS FLOWN PER
FATAL ACCIDENT YEARLY BASIS



Learning Curve

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ORIENTATION OF A GOVERNMENT REGULATORY AND ENFORCEMENT AGENCY FOR THE DECADE 1970-80

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In a truly democratic society, the precise orientation of its governmental regulatory and enforcement functions as related to a particular industry, is extremely difficult to predict for more than a few years into the future. Such a projection is dependent on many political, social, and economic influences which are not directly associated with that industry and which are themselves virtually impossible to accurately foresee. Therefore, it generally is safer to place greater reliance on the historical rather than the anticipated climate of public interest and support.

Historically, public acceptance and support of air transportation in the United States has been an evolutionary process with a relatively stronger affirmative pattern in recent years. There is no reason to believe this pattern will change appreciably in the next decade.

In the past decade, the U. S. aviation industry has matured much faster than during the decade immediately following World War II. A by-product of this maturity has been the industry's increasing desire to take over or participate in many of the regulatory and policy making functions, which, historically, have been discharged by the government. Because the future development of aviation will increasingly be a joint effort of the government and the more mature industry, the private sector will have a greater voice in shaping its own destiny. The government will make every effort to provide industry with greater opportunities in these areas.

In the next decade, for example, it is quite likely that private industry will take over increasingly more of the actual testing of airmen for licensing, even though the issuance of licenses will continue to be the sole responsibility of the government. Similarily, industry must assume constantly greater responsibilities in the aircraft certification process under delegation of authority from the government. There will be a corresponding decrease in the amount of government effort devoted to surveillance and inspection of the aviation transport business. For example, the government's role in this area will be a "sampling" and "special case" type of surveillance and inspection through the use of a sophisticated flight and maintenance recorder system.

Conversely, the functions of airspace regulation and control cannot be readily delegated to private enterprise since they deal with a national resource -- the airspace. Therefore, the government's role in these areas will expand as a result of the need for much tighter regulation and regimentation of the airspace to maintain a high level of safety for air travelers. Also, as a result of a forty percent growth in the size of the airline fleet, a seventy percent increase in the size of the general aviation fleet, and a tripling in the number of flights controlled by the air traffic control system, a much larger and more technically sophisticated government-operated national airspace system will be needed. Greater size, speed and density of planes using the airspace will require lowering of positive control airspace - in some areas down to the surface - to eliminate "unknowns" in highly congested airspace; use of the "see-and-be-seen" type of collision avoidance will no longer be prudent.

Tighter control of the airspace will lead toward more disciplined pilot procedures and airplane performance just as today's standards are more exacting than those in existence ten years ago. Flight tests and written examinations will be more comprehensive and more systems oriented, airplane equipment standards will also be more systems oriented, cockpits will have more sophisticated equipment - especially for operation in the higher density traffic areas.

Much closer surveillance of the operating performance and maintenance of the airline fleet will be accomplished by the use of multi-channeled maintenance flight recorders and highly sophisticated central computer installations on the ground. These systems, which undoubtedly will be operated either by individual operators or by some other form of non-government enterprise will permit substantial reductions in the amount of time that aircraft equipped with the recorders are out of service for routine maintenance inspections and for repair. It also will permit the government to discharge its surveillance functions with greater effectiveness. The use of new flight recorders with more than one hundred channels of information will also sharply reduce the need for in-flight cockpit surveillance, since both the aircraft owner and the government will have access to recordings of individual crew performance in penetrating detail.

The demand for more and better training will prompt an increasing number of private educational institutions to establish a wide range of aeronautical courses to fulfill the needs of virtually every phase of aviation activity. Initially, the government will play an active role of encouraging and promoting such training by private institutions. Before the end of the next decade, private enterprise will have asserted a much more predominant role and the government's role will be one of surveillance on a modest level to assure adequacy of the instruction which, in most cases, will satisfy knowledge prerequisites for airmen licenses.

In the area of airport safety, government and airport operators will devote an increasing amount of effort to developing national design and operating standards for all public airports. Fire and crash rescue equipment and training of ground crews will be emphasized and improved.

In spite of airport improvements, however, the major safety emphasis insofar as crashes are concerned, will continue to be directed toward improving aircraft crashworthiness and fuel containment. The plain fact of the matter is, in more than ninety percent of the airport crashes the airport ground environment and crash equipment have virtually nothing to do with the severity of the accident. In other words, the greatest improvements that can be made in the passenger's chances for survival in airport crashes are in the area of improving the crashworthiness of the machine itself.

Historically, a major role of the U.S. Government has been in encouraging and promoting the development of the aviation industry. Now, with the industry reaching maturity, there is a diminishing need for the government to play an active role in this area. As the government gradually sheds this responsibility, the taxpayer will be relieved of the burden of subsidizing various parts of the industry. Users of the nation's airspace must assume the full cost of the civilian portion of the National Airspace System. This, again, will tend to promote even greater cooperation and team work within the aviation community, since, collectively, it will be the major "stockholder" in the system.

In summary, the complexion of the U.S. Government's regulatory and enforcement functions will change considerably during the decade 1970-80. In almost every area where private enterprise is competent and capable, it will assume greater responsibility. In areas where responsibility cannot be delegated to individual parties or to a consortium of aviation interests, the government's role will expand to keep pace with the industry's growth. This, of course, is a classic example of the traditional cycle in the development of a major U. S. industry under a free enterprise, democratic system of government.

ACTION ITEMS FOR 1970-1980 AIRLINE SAFETY

Captain William W. Moss
Pan American World Airways, Inc.
Jamaica, New York

In his exhaustive paper on the Technical Aspects of IATA in the 1970's, J. T. Dyment said: "It can be forecast with confidence that air transportation will, within ten years, become twice as safe as today and it will have no rivals in transportation safety."

At first glance, this appears to be a big jump but when it is realized that this calls for less than a 10% increase in safety each year it would appear to be an attainable goal. It is, nevertheless, an ambitious one when the aircraft that are being introduced in this time period and the forecast rate of growth of airline transportation are considered. At this time we can already identify the B-737, B-747, DC-10, L-1011, Concorde, and B-2707 as "Third and Fourth Generation Jets" and there are sure to be many more other new types by the end of the 1970's. Forecasts of traffic indicate that in the late 1970's, passenger miles will be 2½ to 3 times larger than today while cargo ton miles will be 8 to 10 times greater.

The question then is: "In the face of new aircraft introductions and a rapid traffic growth, what specific items are necessary to achieve the predicted safety record improvement?"

In order to answer this, the identification of accident causes is vital. An analysis of all worldwide fatal jet aircraft accidents has been made yearly for the Flight Safety Foundation and it is mostly from these papers, "Special Aspects of Jet Statistics", (1) that the following facts are presented. These are based on more than 22 million hours of jet transport operation.

1. Distribution of fatal accidents:

Takeoff	18%
Climb	15%
Cruise	10%
Landing	57%

2. Night approaches and landings are 3 to 4 times more hazardous than day approaches and landings.

3. Training accidents account for 19% of the total but only 3% of flying hours.

4. A very disproportionate amount of accidents take place where navigation and traffic control facilities are poor.

5. A disproportionate number of landing accidents occur where no glide path information -- visual or electronic -- is available.

6. A definite learning curve is evident following the introduction of new aircraft.

7. When a pilot is qualified on an aircraft, the first three hundred hours of command time appears to be a critical period. Accident exposure per hour is approximately 15 times greater than the average for the remainder of his flying time.

8. A type of accident becomes prevalent and then disappears virtually overnight in response to educational, procedural, or aircraft modification efforts.

In reviewing the above, it is clear that the most effective area for action is the approach and landing, followed by training. Intertwined with these is the question of the accident exposure rate of the low time pilot. Finally, there are the other phases of flight where many actions can be taken which will improve the safety record, but to a smaller extent.

To this observer, the following will be necessary to achieve a safety record twice as good as today's:

1. Glide path guidance -- visual or electronic -- for all runways -- day and night.

2. Some form of descent guidance covering the portion of flight from top of descent to the final approach.

3. Terrain clearance indicators to supplement barometric altimeters.

4. Automatic approach and landing equipment with associated monitoring instrumentation.

5. Improved cockpit presentation of approach and navigation charts, especially with reference to readability at night.

6. Simulators with adequate visual attachments to provide realistic training in all phases of flight. The objective is to give better training and do all of it in simulators.

7. More comprehensive pilot line qualification on new equipment coupled with more intensive supervision thereafter, especially during the initial critical period. In this connection, the use of multi-parameter flight recorders with programmed computer surveillance of operating techniques appears to be the most promising way of accomplishing this function.

8. Better braking coefficients on wet or slippery runways whether by runway surface preparation or by better brakes, tires and landing gear design.

9. Reappraisal of the runway length requirements for the takeoff accelerate/stop case. Over half the takeoff accidents have involved aborted takeoffs.

10. Collision avoidance system. Not only must there be a system which will prevent collision between two airliners but there must also be found a way to prevent collision between airline aircraft and private or business aircraft. The collision hazard is growing rapidly.

11. A better understanding of and preparation for the new or changed characteristics or problems of new aircraft types. Every aircraft seems to bring some new problems when first introduced. These need to be promptly identified and expeditiously handled either through redesign or by modification of operational procedures. It is, of course, preferable that all of this should be done before entering service and it is here that advance analysis can produce big dividends by starting the aircraft's safety record high up on the learning curve.

12. In addition to these new items, there must be a continual refinement of procedures and organization throughout the industry by:

Airline operators
Aircraft manufacturers
Airport authorities
Air Traffic Control authorities
Regulatory authorities

in order to produce the small but continuous gains which in the end contribute so much to the safe and efficient operation of airlines. With the coming of second generation personnel in these organizations, more modern management techniques, and the unlimited promises of computer technology, perhaps these gains may be considerably speeded up.

Before the period being considered here is over, new problems will arise and new solutions will present themselves. However, based on past experience the above actions, in addition to the continuing meticulous attention to the myriad details which has produced today's safety record, should provide the initial and continuing impetus toward the achievement of the objective of doubling the safety of air transportation in less than ten years.

Reference:

(1) "Special Aspects of Jet Statistics", 1963, 4, 5, 6, 7 - William W. Moss Flight Safety Foundation

AIRLINE ENGINEERING ASPECTS OF SAFETY *

J. T. Dyment
Chief Engineer, Air Canada

Customers need not buy air transportation unless they want to; that is, unless they feel that the risk involved with the current state-of-the-art is acceptable in view of time and money saved in travelling by air.

But aviation is a business with risks. If there is an emergency, one can't just slow to a stop. One of the main risks is its high speed of impact. High speeds also reduce the time available for making decisions and reacting. The airplane is frequently matched against the elements of nature. An airplane can also be the most unforgiving of all vehicles if mishandled.

However, if all the developments that could be adapted to make flying safer were included in the present state-of-the-art of airplane design, the payload would probably be insufficient to pay for its operation.

An airline cannot be expected to stay in business indefinitely if it is losing money, so it must assess all the known ways of improving safety and implement them on a priority basis, based on very many factors.

Designers and operators are thus continually compromising in their endeavors to obtain the maximum degree of safety that is practical while still providing adequate performance to permit a profitable operation.

The passenger is not interested in how safe statistics show air-transportation as a whole to be. He is only interested in his intrinsic chances of reaching his destination safely.

It has been estimated that in the next 5 years there will be 70 fatal accidents on scheduled services during the approach and landing phase, 40 to 50 accidents will occur from hitting hills or mountains and there will be 12 mid-air collisions-not a very happy thought especially when this is extended to the increased traffic of the 1970's. It is not necessary if quick implementation is made of a number of developments available today, at a price.

The speed of approach has been increasing slowly but steadily from the beginning of aviation. Now it is double what it was twenty years ago. Speed itself does not cause accidents because of improved instrumentation and braking characteristics of the airplane, but it is the short time available for the pilot to recognize a situation, decide what to do, do it, then wait for the aircraft to respond, that causes the trouble. A tremendous improvement in safety could be achieved if airplanes could be designed to approach at 40 mph instead of 140 mph.

Boundary Layer Control utilizing an air pump in the form of current turbo-fan engines has not been used yet to achieve low approach speeds, but it should have great potentialities. B.L.C. could also permit steeper take-offs and approach angles and thus increase the clearance between the airplane and obstacles near the airports.

A pilot should also be able to see what is ahead of him as clearly under zero visibility conditions as on a clear day by a heads-up display on his windshield or the equivalent. By some improved combination of radar, infrared, television presentation, etc., he should be able to look ahead through his windshield and see through fog and clouds as if they did not exist. Pending the evaluation of a 100% reliable T.V. presentation of what is ahead, considerable improvement is still required in ordinary visibility through the windshield during conditions of heavy rain, icing, glare, etc. Also every runway should be equipped with a visual glide path indicator. They only cost about $400 each.

Inadequacies in current airplanes induce pilots to make "errors." Some airlines are still using the three pointer altimeters which have been misread periodically and have caused accidents throughout 40 years of air transportation. There are many indicators available today that would be most difficult to misinterpret.

For 40 years airplanes have also been letting down into hills or striking mountains a few feet from the top because the pilot was in a different point in space than he thought he was. There have become available in the last few years instrument systems that will let the pilot know exactly where he is in relation to the terrain below, that is, his geographical location and height above the ground. This equipment is past the experimental stage but it is still expensive.

The outputs of a typical system are: bearing, distance/time, vertical profile, latitude/longitude, flight level, tie-in with auto pilot, and pictorial display. This information is provided from one or more inputs such as VOR/DMET, Decca/Dectra/Loran C, TAS/ALT (KIFIS), Doppler, Inertial, Polar Path Compass, etc. No mental gymnastics are required for the pilot to see by a glance at the pen trace on the map where he is flying in relation to the terrain below and how far he is above it. Such equipment should be considered essential for all future air transports, and I believe it would pay to retrofit existing big jets with such a system.

Instruments must be devised to enable a pilot to avoid severe turbulence, expecially clear air, and then tell him what to do when he does encounter turbulent conditions, whether clear-air or not, instead of the kind of contradictory information that is presented to him today. For example, a down-draft from the upper rear direction will cause an airplane to pitch-up. The attitude indicator and air-speed indication tell the pilot to push on his controls but the altimeter, vertical speed indicator and his own feeling of acceleration, will tell him to pull back on the control column. Such ambiguity must be eliminated by instrumentation so that a pilot will have confidence in ignoring his own notoriously bad "feel indication" and rely with confidence on a consistent group of instruments.

A system is also required to prevent mid-air collisions by indicating to the pilot the evasive action that should be taken or, if desired, by feeding this information into the automatic pilot system. At the present time the only device that appears practical in this area is the Macdonnell EROS System in which both airplane on a collision course must be so equipped. The cost per airplane makes it unlikely that many general aviation owners can afford it. Airlines cannot afford not to install such equipment, or its equivalent, as soon as its reliability is established. The industry must take every step to prevent the possibility of two jumbos colliding.

The major airlines try to keep their pilots abreast of the characteristics of their airplanes but the airlines do not always receive adequate information from the manufacturers on the characteristics of new airplanes when flying in other than normal conditions. A number of jets were lost because of the difference between their flying characteristics and the previous propellor driven airplanes. Needed information was established by the manufacturers after the accidents occurred. This is partly the fault of the airlines because the manufacturers are continually pressed for early deliveries and so are unable to do much more flight testing before delivery than that required to obtain the Type Certificate. A more comprehensive flight test programme is required before a new type should be permitted to go into service.

The practical way of achieving this is by government regulation to make the additional testing mandatory.

All airlines must ensure that their pilots are kept abreast of latest theories in meteorology. Airplanes have been lost in recent years penetrating line squalls and being torn apart by wind shears.

Airplane control characteristics have caused many fatal accidents, particularly due to undershoots with jets. The characteristics of an airplane should be such that the airplane will respond immediately to the action of the pilot to flatten its approach angle rather than for it to continue to sink for a bit before responding.

Airplanes should also have full lateral control at all times even in a stall under icing conditions or from a turn, and they should be quickly recoverable with no violent pitching action or tendency to remain in a stable stall situation. This control at low speeds has been achieved in the past so should be a target to achieve again with the present more sophisticated high speed designs.

There are few occupations in which one must adhere so rigidly to instructions as in flying. Because of the infinite number of variables and circumstances that can be encountered in the profession, errors in judgment are bound to occur. The airline must strive to ensure that its operating procedures are such as to reduce the human element to a rock-bottom minimum. Someone has suggested a Disciplinary Code in which there would be no penalty for an error in judgment but severe disciplinary action for negligence. For instance, if a pilot lands an airplane successfully under clearly below-minimum conditions, he would be fired. If an error of judgment is involved, it must be established, however, why the error could have been made and action taken by the airline to prevent a recurrence.

Because people can gradually drift from approved procedures, the installation of a flight recorder in airplanes of the future will enable supervisory personnel to determine if a pilot is acquiring unacceptable habits of flying and bring them to his attention. It would also reduce by the record of his individual performance the need for a check or refresher course. A comprehensive flight recorder would also provide information of inestimable value in establishing the condition of the airplane's equipment and thus forestall trouble that might lead to an accident.

A most important requirement is the reduction of mental stress in the pilot and thereby enhance safety. This can be accomplished by simplifying the entire job of the pilot rather than through the multiplicity of instruments and/or people.

Crew complement will probably remain debatable but the cockpit and its controls must be designed with sufficient simplicity that the airplane can be flown by one person whether he is in the left hand or the right hand seat. The person in charge of flying must have the ability in an emergency to make the decisions on the desired action and to take the action himself. It is essential for the cockpit to be designed to make the combined action of two human beings unnecessary under hazardous circumstances.

This can be done by suitable cockpit design and it has been done successfully in all but one of Air Canada's 4-engined airplanes.

If a pilot could see ahead under any weather conditions and approach at really low speed he would not need automatic approach equipment. This situation is not likely to exist for many years. Efforts must continue towards achieving the every day use of automatic approach and landing. The importance of achieving FAA CAT. III in automatic approach and landing cannot be over estimated. Although the economic gains will be considerable, the increase in safety will be very considerable. It will eliminate that most dangerous area today when a pilot is in the transition period between relying fully on his instruments and relying fully on the airport visual aids.

A major problem of course is in obtaining the implementation of the necessary ground aids.

It is a most difficult task because of lack of appreciation of the benefits that would result and consequent unwillingness to appropriate funds.

Everything practicable must be done to reduce the fire hazard in air transportation. The chief problem is to prevent fuel being sprayed about when a tank is ruptured, because all fuels are readily ignited under such conditions.

Current prospects for reducing this hazard could be through the use of emulsified or gelled fuel, or by filling the tanks with a sponge-like plastic that does not involve much of a penalty to tank capacity. These possibilities have not quite reached a practical stage for airline use but might within a few years.

A useful device is the explosion detection and suppression system used by TWA. Another means of preventing an explosion under particular conditions is through the widespread use of an anti-static additive in fuel. Many airlines have already been using fuel with an anti-static additive for years, with no filter problems.

There is no doubt that kerosene is safer than JP-4 under certain accident conditions but, conversely, JP-4 could be preferable in other circumstances. It will be recalled that the U.S. Government appointed an independent body of experts to assess the situation and their conclusion was that neither fuel had a distinct advantage over the other from an overall safety standpoint.

It is believed essential for all large airplanes of the future to be equipped with a weight and balance indicator as a check against mistakes in loading. Through the use of such an indicator, the airplane could also be more easily loaded to achieve the optimum balance and, hence, fly with minimum drag and fuel consumption.

Hydroplaning is still causing accidents. More work is required in establishing the best combination of tire tread and runway grooving to reduce the likelihood of hydroplaning.

Studies should continue to find the cheapest method for eliminating ice. There is a need for a non-corrosive chemical that will remain effective when deicing runways through a wider temperature range than the currently used UREA, which later is not effective below 15 degrees Fahrenheit.

In conclusion, success or failure in achieving higher standard of safety will depend on many people--the pilot, maintenance man, designer, air traffic controller, meteorologist, etc., but above all, it will depend upon airline management.

It is only management that can instill in everyone the enthusiasm for doing his job conscientiously and efficiently; it is only management that can establish how much responsibility the airlines should take on themselves in adopting new ideas for improving safety. For instance, it should not have been necessary for the FAA to establish regulations in order to ensure that all transports can be evacuated in 1-1/2 minutes or to prevent cabin materials being used that create heavy smoke or toxic gasses when they burn. These are self-evident and should have been adopted by the air transport industry without waiting for regulations for their implementation. Notwithstanding certain inadequacies on the part of the industry, it should be emphasized that the airlines devote literally millions of dollars worth of time, effort and equipment to continually improve the safety of air travel.

*Condensed from a more extensive presentation.

RESEARCH FOR AIR SAFETY IN THE 1970-1980 DECADE

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I. Introduction

A substantial expansion of aeronautical activity will occur in the next decade. Larger jet aircraft, small "miniliners," and improved V/STOL aircraft will be required to transport more people and cargo to more places more frequently than ever before.

All this augurs favorably for generation of jobs, expanded business, and general prosperity. The bleak side of the picture, however, is the reality that accidents occur, with loss of life. Research for air safety in the next decade is therefore of prime importance. A.M. Lester's predictions of passenger fatalities in ICAO world scheduled air service in the 1970-1980 decade average about 1100 per year, with an additional 400 fatalities per year in nonscheduled operations. The actual figures, as Lester points out, are sensitive to the increasing capacity of the new larger jet aircraft, wherein one accident event would involve relatively large numbers of people. A single accident with a large airplane could thus skew the statistics substantially.

II. The Nature of Safety Research

The basic task of Safety Research is not directed at statistics, however, but toward the reduction of injuries and fatalities. Safety Research traditionally operates with a double objective:

1. To prevent the accident and

2. To maximize occupant survivability in case of an unforeseen accident.

This objective is generally sought by basic research; by disciplinary research in the fields of Aerodynamics, Structures, Propulsion, Flight Dynamics, Biotechnology, and Avionics; and by directed research on specific problems. Risks are therefore reduced by incorporation of engineering improvements to increase flight efficiency and reliability, as well as by solving specific hazards problems and implementing the solution. Much of the safety research effort called for in the coming decade will be simply a continuation or an extension of existing efforts as new aircraft designs evolve. As the aircraft's operational envelope expands, continuing research is necessary either to verify that old solutions found for "traditional" safety problems still apply or to modify old solutions so that they are compatible with newer problems. Probably the most difficult task facing the safety researcher and the research planner, however, is the identification or anticipation of new problem areas occasioned by the introduction of new materials, new fuels, new operational techniques, and so on. Too often, these problems are tragically "identified" by an accident because some facet of risk had either been overlooked or given insufficient attention.

An editorial appearing in Interavia not long ago views the problem quite succinctly: "When a passenger elects to travel by air he accepts the fact that the operator is licensed for the route, the aircraft has a certificate of airworthiness, and that the air traffic services are manned by qualified and licensed personnel, as guarantees that he will not be placed in hazard. It would be a serious matter if he ever loses this confidence and begins to question whether there is any lowering of standards." The Safety Researcher plays a key background role in providing data upon which realistic and rational standards can be based.

III. Operational Safety Problems and Related Research Needs for the 1970's

The current generation of jet transports will continue to be the "backbone" of the world air transport system, but will be augmented in the coming decade by new types of aircraft and operations mentioned previously. While it is impossible to present in the space of this paper an exhaustive discussion of aviation safety problems facing the researcher, it may be instructive to outline several representative problems in the contexts of aircraft species and environment.

A valid question can be raised throughout the discussion: Are the problems solvable by employing current technology, or is new research data needed? There is no straight yes or no answer, since very often the true nature of the problem remains hidden until uncovered or determined by research, while the "fix" can be provided by current technology.

Careful studies of a new or an enlarging operation can determine where technology gaps lie and research can be applied.

The "miniliner" or so-called third-level airlines, while not representing a new technology, nevertheless constitutes an employment of existing light airplane design practice in a new environment. It is true that air taxi and charter services are nearly as old as aviation itself, but these aircraft will be called upon to provide short haul feeder service to an extent never realized before. Yet these aircraft, with their solid-state micro-electronic circuits, composite material structural elements, and iceload-sensitive high performance airfoils, will operate in great numbers on regular schedules over short stage lengths at low altitudes, where they will be exposed to the environmental hazards of hail, ice, low altitude turbulence, and lightning strikes. It seems that many of the problems which were minimized by achieving the higher operational altitudes of today's jets, are facing us again, with an increased number of aircraft involved.

As a case in point, a recent NASA operational flight loads (VG-VGH) survey of a representative sample of general aviation aircraft revealed that present piston-powered light twin aircraft involved in typical passenger carrying operations are flown in rough air between 38 and 45 percent of their entire flight time. By comparison, the large commercial jet transports average between 3 and 12 percent of their total flight time in rough air. Typical personal owner aircraft may accumulate 100 to 500 flight hours per year, while the same technology will produce identical and "stretched" versions of these same aircraft types for an operation anticipated to utilize them for 2000-2500 flight hours per year. This intensity of utilization, coupled with the large exposure to rough air raises some interesting questions regarding structural fatigue research needs and current design criteria.

The miniliner will share the low-visibility landing problem with their big brothers, without the luxury of payload margin to carry extensive amounts of avionic equipment for navigation and landing aids. This smaller weight allowance for avionics will, of course, spur the employment of microcircuitry and solid-state devices. An interesting question is posed: What is the effect of a lightning strike to the airplane on these microcircuits? What are the magnitudes of induced electrical surges which must be protected against? Additionally, little is known of the behavior of newer composite materials when subjected to a strike. Radomes have been afforded effective protection by incorporating conductive tapes or strips in the nonmetallic surface, but the extension of this method to protect more critical structures, e.g., wing tips, leading edges, etc., needs careful examination.

Engineering information on airframe icing is extensive. Yet today, we witness icing problems with turbine engine inlets and piston engine induction systems where no systematic engineering analysis has predicted a means of avoidance in the design stage of development. Small diameter engine inlet Reynolds Numbers are much more sensitive to typical ice formations than are large engines, and the heat sink provided by "slugs" of wet snow or slushy ice ingested by the small engines taxes their ability to avoid severe surging or flameout. In addition, the damage to small diameter engine compressor blades from ingested ice broken loose from inlet screens has been substantial. Here is an area where current technology can probably provide an effective solution once research investigations determine the boundary values of the problem.

This overall third-level airline operation should constitute a fertile field for researchers to plow, in order to provide the manufacturers and operators with the data they need to assure, to the greatest extent possible, avoidance of potentially calamitous problems. Here is an opportunity to provide solutions for problems with which some familiarity has already been gained on a relatively small scale and for comparatively modest sums.

The "Jumbo Jet" aircraft will employ new technology elements. The sheer size of this aircraft type will create extensions of the older and existing problems for the safety researcher. Fuel and hydraulic lines will be larger and longer, offering greater vulnerability to damage. Fuel tanks of greater volume will be located near and under the passenger compartment indicating an urgent need for fuel containment in case of a crash landing.

In flight, the large radius leading edge of the wing may offer new problems from the hazards of bird impact and ice accretion. The threat of birds is not to be taken lightly, since such impacts would tend to puncture the skin, rather than be deflected. Unless protection is provided, the electrical and fluid lines normally found immediately behind the leading edge surface could be damaged, possibly resulting in serious system failures. There is little data in existence regarding the icing characteristics of large radius airfoils. The large area of near-normal surface presented by the large radius leading edge may prove to be an efficient ice collector, with consequent large power requirements for deicing or anti-icing. Research is needed to provide a rational means of dealing with ice accretion here. Large helicopter blade ice formation, prevention, and removal is incompletely understood, and research is needed both in hover and forward flight modes.

The supersonic transport will cruise at altitudes and speeds where aerodynamic heating imposes new problems on the systems designer. Quests for suitable onboard sinks for the airframe- and cabin-generated heat involve the fuel supply. Raising the bulk fuel temperature reduces the ignition-delay time of the fuel, and provides a favorable environment for the formation of cool flames. While cool flames are somewhat benign and self-extinguishing under normal circumstances, the possible modes of transition from cool flame to normal burning have not been fully established, and data of this kind would be of high importance to the aircraft fuel systems designer. Fuel tank atmosphere inerting systems concepts need to be explored more fully. Other needed research includes the determination of the effect of fuel bulk temperature on autoignition temperature, component isolation techniques to minimize autoignition, and techniques and methods of packaging and deploying extinguishants in the SST environment.

The increasing use of high temperature alloys and composites could pose a problem if the effects of lightning strikes to them are not understood. Recent NASA-sponsored tests of simulated lightning strikes to stainless steel and titanium alloy sheets show a tendency for some spalling of hot fragments from the opposite side of the surface receiving the strike. In addition, the low electrical and thermal conductivities of these alloys allow a longer persistence of a hotter hot spot following a strike. Coupling this behavior with a titanium or stainless steel surface "wet wing" of an SST (with its high bulk fuel temperatures and the consequent shorter ignition delay time of the hot fuel) clearly outlines the necessity for research on methods of employing these alloys in such a manner as to avoid a potential hazard. The friction sparking characteristics of these alloys, compared with the docile behavior of aluminum, also calls for research directed at the suppression of friction sparks in a potential gear-up landing situation.

While the foregoing discussion deals primarily with identifying mission-oriented research needs, there are numerous problems ahead which apply to all types of aircraft. The following listing, while not exhaustive, is representative:

Bird Impact Hazards: While primarily an ecological problem closely related to the national pollution situation, the need for aircraft protective devices, such as stronger, bird-proof windshields, and engine inlet guards for small engines prevails.

Clear Air Turbulence: Continued effort in the search for means of reliably predicting clear air turbulence encounters is needed.

Collision Hazard Warning: Current technology appears to offer no practicable passive means of warning a pilot of an impending mid-air collision with other aircraft. As the numbers of aircraft increase over the next decade, a reliable, non-cooperative, pilot warning device will be needed, and research must be employed to provide the technology for such a system.

Low Visibility Landing: Continuing research is needed on the two approaches currently being followed...modifying fogs to improve visibility, and improving aircraft terminal guidance to permit safe landings in poor visibility situations. Related to this is the need for an effective means of measuring slant range visibility along the landing approach path.

Ice Bond Strength: New materials have appeared on the engineering scene within the past few years which offer the possibility of smoother aerodynamic surfaces. The effects of reduced surface roughness on ice bond strength should be re-evaluated in the light of possible reduced energy requirements for ice formation prevention or removal.

Explosion Resistant Structures: Cases of sabotage, bombing, and bomb threats involving passenger-carrying aircraft have spurred the development of explosives detecting devices. These devices should do much to prevent a bomb-type accident. Research should be directed toward evolving design principles to minimize the effects of an explosion aboard an aircraft in flight, especially to insure the preservation of aerodynamic and control integrity to guarantee survival of the airplane in such a situation.

Crashworthiness, Fire Protection, and Occupant Survival: Probably the major thrust of current Safety Research is in this area; however, there is no indication that the need for continued effort here will diminish in the next decade. We have seen improvements in impact survival, due in part to improved retention of seat and passenger to the airframe, and to the larger mass and structural integrity of the airframe. Those who survive the impact must promptly evacuate the airplane, or they may quickly succumb to the effects of fire, smoke and fumes. The survival of the occupant constitutes the major challenge to the researcher, and so much is being done currently that it is difficult to identify unexplored problem areas. Clearly, continued research is needed on modified fuels, fuel containment methods, fuel vent fire suppression, smoke suppression or inerting, protection from smoke and heat, evacuation improvement, seat/occupant restraint improvement, and ignition suppression. An assessment should be made of the potential fire hazard problems associated with the ramp servicing of large jumbo jet and SST transport aircraft while connected to the passenger terminal building by several "jet way" passenger tunnels. Residual tank fuels in the SST will be at elevated temperatures, with a consequent shortened ignition delay time. The chimney draft effect of the passenger tunnels on the propagation of a ramp fire into the terminal building needs careful assessment. Extensions of current research should be made to carry military-sponsored investigations of vertical load absorbing seats for helicopters into civil applications. While there is a wealth of biological data concerning the acceleration tolerances of humans, it is preponderantly limited to healthy young male military types; corresponding tolerances should be established for the "median" air traveller and protective systems design should reflect these probably somewhat lower tolerance levels.

IV. Summary

There appears to be no diminution of the Aviation Safety Researcher's role in the future. Indeed, the increasing complexities of the rapidly growing air transport system indicate a strong need for an increased safety research effort by both Government and industry over the next decade.

The most difficult task ahead is identifying subtle potential hazards in new designs or new operations. Extension of past and current "traditional" problem research into the expanding design and operation envelopes is of great importance to insure occupant safety and survivability.

Aviation Safety Research has grown from an after-the-fact "panic fix" activity of many years ago to an essential ingredient of the design and operation team, and its continually growing importance cannot be underrated.

Over the next decade with careful, high quality research, significant progress should be possible toward making aircraft crash fire deaths a thing of the past.

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PROPOSED A.T.C. SYSTEM 1970 - 1980

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Working to a time scale of between five and ten years from now, it should be possible to move progressively over to an A.T.C. system comprised of the following basic elements:

1. A large on-line ground based data processing complex to handle such A.T.C. functions as flight planning and clearances, route and altitude allocation, flow control, and in-flight monitoring and sequencing.

2. An automatic digital air/ground and ground/air communication system whereby operatoral centers, aircraft and the ground data processor can all exchange routine information on a programmed basis.

3. A means of airborne recording for pilot useage of significant messages both ground/air and air/ground (such as for example a miniature printer).

4. A highly accurate area coverage navigation system especially for high density terminal areas. To achieve the necessary accuracy a ground based hypobolic method of position determination seems the only practical means within the specified time scale. It is not essential at this stage to decide on such features as low against high frequency, time measurement or phase comparison, or pulse versus continuous wave. In fact, two systems using the same real estate but working on different principles may turn out to be the best solution. Guidance in the vertical plane should also be provided as soon as possible.

5. A pictorial cockpit display of navigational data so that pilots can fly precisely and reliably the patterns prescribed by A.T.C. in a relaxed and natural fashion.

6. Instrument approach aids to be provided on all runways to permit landings from 200 foot critical height. These aids can be used also to supplement the navigation system when closely spaced parallel runways are in use and, if an appropriate airborne antenna is installed, can assist the noise abatement programme by defining the optimum take off path.

7. An air-to-air proximity warning system so that pilots are aware of the relative position of other aircraft in their vicinity. If a collision avoidance procedure can be devised economically it might be advantageous. However, the main requirement is for a system that enables pilots to assist A.T.C. in the task of optimum spacing and also provide tranquility of spirit in the cockpit with close sequencing in IFR conditions.

8. The data processor will be fed with air derived and ground derived data, both to provide a desirable element of redundancy and to enable aircraft with minimum equipment to be handled by the system. In the latter case private aircraft equipped with a small box weighing only a few pounds and requiring a few watts, can generate a signal automatically whereby their identity, altitude and precise position can be transmitted to the A.T.C. data processing system at intervals of a few seconds. This can use the same principles and real estate as the air derived navigation system transmitters occupy and is both more efficient and more economical than radar.

9. Altimeter accuracy should be greatly improved to enable the fullest possible use to be made of vertical separation.

10. Speed variation within aircraft's normal performance envelope must become an accepted A.T.C. tool to effect optimum time spacing.

11. Significant weather information will be fed into the data processor so that the routes and altitudes allocated to pilots facilitate avoidance of such unfavorable flying conditions as thunderstorms and icing areas.

12. Airport provision and design also their use to maximum capacity by incorporating enough landing aids, runways, taxi tracks, apron space and passenger handling facilities represent a vital element in the A.T.C. system. Integration with other systems of ground transportation must be efficiently organized.

13. A system of priorities for landing and departure paying due regard to the interests of the aviation community at large should be established in the public interest.

The cost of moving to a new A.T.C. system can be justified on the following grounds:

1. Increased safety for all airspace users.

2. Increased efficiency in the air and on the ground.

3. Lower annual operating costs.

4. Increased traffic capacity.

5. Alleviation of the serious A.T.C. manpower problem in recruitment and training.

6. Facilitating minimum crew operation.

7. Reduced training costs.

Aviation Weather Service and Requirements 1970-1980

Newton Lieurance*

There is a whole spectrum of meteorological problems associated with aircraft operations including air traffic control in the years ahead. These must be solved in order to continue the excellent safety record of aeronautics. With the advent of high-speed aircraft, expanded use of aircraft in pleasure and business flying, the jumbo jets with up to 500 passengers aboard, and the V/STOL aircraft, everything we do today must be done better tomorrow and lead time is short.

Aircraft operations in the decade of the 70's will be more global in nature rather than regional or local as in the past. The World Meteorological System, operated by a community of nations, is important to the safe and efficient operation on an international basis of all classes of aircraft operations. It is through this world system that the dynamic state of the atmosphere over the globe (temperature, wind and pressure) is determined and predicted, and this basic information is vital in the prediction of specific weather elements (ceiling, visibility, precipitation, turbulence, winds, and temperature) important to aviation.

The World Weather System produces vital intelligence concerning the atmosphere. This must be considered an important adjunct to the world air transportation system, including air traffic control. Since the World Weather System and the Air Traffic Control System are autonomous and since both have some mutual weather responsibility, there must be an effective means of communication between them to apply, distribute, display and present the operationally significant weather information on a timely basis for the controllers, pilots, and operational planners. Such communication does not presently exist. If this system gap is eliminated, noticeable and immediate improvements in the orderly and safe flow of traffic can be realized.

In the post-1970 period, the World Weather System should have greatly improved capability including weather radar, weather satellites, and the analysis and prediction of the state of the atmosphere up to 100,000 feet, utilizing high-speed computers. Radar will be capable of detecting severe weather and providing conflict displays to air traffic control. Poor visibility as a result of fog can be improved by weather modification techniques so that adequate visibility for visual landings and take-off can be maintained under most conditions.

However, technical gaps must be eliminated for future improvements, especially in the light of increased traffic. The terminal area is defined as the air volume within a cylinder of about 100 miles diameter extending up to about 30,000 feet. This area is the most critical from the viewpoint of planning, dispatch, operations and air traffic control, and the elements of most serious concern are visibility, turbulence, and icing. Accurate observations and forecasts of these elements are imperative in the years ahead. The inability of the weather system to provide this service by producing observations and forecasts with the accuracy and detail required in the future is a serious technical gap demanding prompt attention by the research community.

The following represent the highest priority weather requirements in the terminal area.

1. Terminal area visibility for approach, landing, and take-off for the ranges of 3 miles or less, with special emphasis on the very low visibility of less than 1 mile.

2. Turbulence in the free atmosphere in the terminal area and on the runway, regardless of the cause, with special consideration given to thunderstorms and squall lines, including areas of hail.

3. Freezing rain and areas of moderate and heavy icing in clouds for the terminal area.

Deficiencies exist in the following terminal area weather observations and forecast services:

1. Wind shear and temperature profile with special emphasis on the wind shear in the lower few hundred feet on the final approach path.

2. Visibility in the final approach with specific emphasis on the runway visibility. This involves new methods of measuring and techniques for predicting the very low ranges, i.e., 1500 feet and below.

3. Airport and, more specifically, runway wind measurements which would provide a more precise index of gustiness.

4. Precisely locating, identifying intensity, and tracking of areas of turbulence, icing and hail.

Much more effort needs to be put forth related to the meteorological problems of en route operations up to 100,000 feet in the following areas:

1. Turbulence of all classes perhaps is the most elusive parameter for the meteorologist to observe, analyze and predict. This is particularly true of clear air turbulence as a result of wind shear in the free atmosphere. Very little is known about the magnitude of this turbulence above 40,000 feet, but there is sufficient evidence to know that CAT does occur in the region between 40,000 and 100,000 feet. Thunderstorms have been observed to extend above 65,000 feet, particularly in tropical latitudes. The extent to which turbulence exists in these convective storms above 45,000 feet is relatively unknown. Here, again, there is sufficient evidence by isolated experiences to indicate severe turbulence can occur at these altitudes in and above thunderstorm clouds. Mountain waves above and down wind of the major mountain ranges of the world can produce severe turbulence in the stratosphere. This is evidenced by actual flight experience at altitudes to 65,000 feet over the great Rocky Mountain range of the Western U. S. More exploratory effort, research and development work is needed in this area to provide sufficient techniques to predict and identify areas of severe turbulence, particularly as it is related to the SST operation.

2. The presence of suspended ice and water particles at the very high altitudes is somewhat an unknown quantity, although it is known that they can and do exist. The presence of hail in the tops of thunderstorms at very high altitudes is also unknown, but again some evidence exists that it can occur at these altitudes. More effort is needed in this area through actual flight and meteorological research.

3. The transition of the SST to supersonic speeds (between 30,000 and 50,000 feet) is in the area of the tropopause where maximum changes in temperature and winds occur vertically as well as horizontally. This will be very critical to the SST operations during the transition from subsonic to supersonic. It is at these altitudes and during this phase of flight that the maximum effort is demanded of the power plant which is very sensitive to high temperatures or variable temperatures.

4. Solar radiation and ozone are perhaps design problems. However, the magnitude of these phenomena is not too well known over the globe at all latitudes. If these are limiting factors, then more should be learned about their nature, extent and predictability. Of particular concern will be the intensity of the cosmic rays as a result of solar storms for flight planning purposes.

5. Sonic boom is alleged to be one of the most critical problems facing the SST program. It is not unreasonable to expect that the meteorological services may be required to provide a prediction of a "least-noise" track for both the en route operations over populated areas and for the climb-out corridors. This is a serious problem and research work is needed to specifically identify the meteorology of the sonic boom.

Much more scientific knowledge of the atmosphere is required before any revolutionary breakthroughs can be expected in forecasting. This is the scientific limitation and will be removed gradually over a long period of time only through fundamental research. This is a problem common to all meteorological services and should be recognized, and adequate effort expended by the meteorological services of the world to eliminate these technical gaps.

In many areas improvements can be brought about if more funds could be made available. This is particularly true in the areas of observations at airports, briefing facilities, communications in the broad sense, and items of this nature. The problem here is one of justification based on a reasonable return for the investment in terms of better operations and/or improved safety. This poses a difficult problem since the operational weather requirements for expanded services are not very well defined and there is not unanimity within government or the industry as to the relative importance of the various services, i.e., more weather radar vs. more communications, etc. There are also different priorities for service to the air carriers as opposed to general aviation. Here, again, the requirements for general aviation are ill-defined. The operational requirements for all spectrums of aviation operations should be quantitized and placed in a priority list for the guidance of the meteorological services of the world.

Conclusions

1. Weather intelligence is one of the essential tools for management of the air space and conducting aircraft operations in a safe and efficient manner. Aviation weather services must be considered an integral part of the world traffic system providing detailed and up-to-the-minute information in a form that will precisely define the environment as it is and as it will be.

2. Meteorological elements having the greatest direct impact on the safety of aircraft operations for the foreseeable future are as follows:

(a) restricted visibilities at terminals, particularly as a result of fog, heavy rain and snow;

(b) turbulence in the free atmosphere as a result of thunderstorms, mountain waves, and wind shear; and

(c) heavy rains, snow and freezing rain affecting runway surfaces.

3. The meteorological elements indirectly affecting safety of flight are:

(a) low-level wind shears in the approach zone;

(b) unusually high surface and en route temperatures;

(c) strong winds en route;

(d) restricted visibilities in the air hampering VFR flight; and

(e) strong and gusty surface winds.

4. The special meteorological elements affecting the operations of supersonic aircraft operations are:

(a) cosmic radiation levels at cruise altitude;

(b) precise temperature information for transition and cruise altitude;

(c) precise information on the existence of rain, hail, and turbulence for transition and cruise altitudes; and

(d) absolute tops of clouds along the route.

5. If airport noise and sonic boom problems cannot be solved by design, the operators, the air traffic control system, and the pilot will have to consider these problems on a day-to-day basis, using meteorological information in the decision process.

For V/STOL operations (short-haul urban transportation) there appear to be no unique weather problems that are identified. However, the same information will be needed for more airports (heliports) and quicker. These factors will be important because of the handling of these aircraft by air traffic control in a mixed environment and the need to maintain a dependable and continuous scheduled operation. An automatic terminal weather observational package with weather radar to detect and track severe storms over the major metropolitan areas is a "must" in the years ahead.

Recommendations

1. Support the funding requirements to improve the over-all World Meteorological System.

2. Work toward the elimination of the systems gap by supporting the establishment of an effective means of communications between the weather system, the pilot and the air traffic control system.

3. Begin to bridge the technical gap by stimulating scientific interest in and encouraging support of research concerned with observing and forecasting of visibility, turbulence and icing in en route and terminal areas.

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THE ALL WEATHER LANDING PROBLEM 1970-80

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During this decade there will be increasing evidence of the close relationship between Air Transport Safety and "All Weather Landing." Although the concept of "All-Weather"--meaning the complete spectrum of weather--is not normally intended, there will be in this time frame economic pressures to operate and land in worse and worse weather conditions. Most specifically, the visibility the pilot encounters upon first seeing the ground from a radio-guided landing approach will be reduced to the smallest amount possible commensurate with the aircraft types, runways and radio guidance of the 1970 decade. Legal and regulatory issues will arise concerning the degree of safety of each application of ILS to lower minima.

It would appear now (mid-1968) that the only thing available during at least the first half of this forthcoming decade will be the improved ICAO-VHF-ILS and existing visual aids for measuring visibility and lighting the approach and landing areas. The ILS system operating in the 100 and 300 mhz parts of the radio spectrum has several limitations if attempts are made to apply it to the lowest visibility landing cases, say, the so-called "CAT IIIB" defined as only 150 feet of forward landing visibility. It is therefore unlikely that "All-Weather" landing of the 1970-75 time period will see anything better than this. There is reasonable doubt that even CAT IIIA (700 feet forward visibility) will be realized with the current ILS.

This is because the number of improvements to the ICAO-ILS, by now a system a quarter of a century old, have been essentially exhausted both technically and economically. Probably, somewhere along the route of lowered visibilities for air transport landing it will be wiser to abandon the existing ILS and adopt a new, modern ILS, one with greater accuracy, precision, flexibility, freedom from siting errors, and probably lower in life-cycle costs than the modified VHF system. Most scientific tests indicate that the "New ILS" will be in the microwave region. The two will coexist on many runways.

This does not imply that the existing ICAO-ILS will not be continued in use for less demanding cases, such as 200-½ (2600 feet of visibility), as it has in many places for years. In fact, this less demanding use of VHF/ILS may accelerate with the introduction of modernized electronic components that markedly reduce its ground station costs. Air Transport service is extending into remote parts of the world and to many smaller airfields where no such capability as "200-½" exists, but often only "VOR let-downs" or low-frequency beacons. Total ILS installations can be expected to expand throughout the world during 1970 to 1980.

This widening spectrum of Air Transport needs for instrument landing facilities includes, however, on the other end such sophisticated aircraft as the 500-passenger jumbo jets and the SST aircraft, possibly desiring even zero-zero capabilities. These aircraft require something far better than the so-called low-cost ILS that may help at the other end of the service spectrum. The jumbo jets in particular have much larger dimensions and economic necessities to land at destination and as a result will create new problems in the use of existing ILS to the lower minima. For example, their more sluggish response requires that the radio guidance align the aircraft at the CAT II "decision height," some 1100 feet from threshold, more precisely since maneuvering will be limited by bank-angle, sink rates and aerodynamic response.

The mere physical dimensions of landing gear that is twice the width of many existing jet transports reduces the accepted lateral runway dispersion. With landing gear widths nearly one-third the width of the useful part of a typical 150-foot wide runway, more stringent criteria for radio guidance, visual guidance and cross winds must be considered. Since over a majority of the major U.S. runways are 150 feet wide, and the existing criteria reflect aircraft of smaller size and greater maneuverability to correct guidance and flight errors, a re-examination of the authorizations for landing these large aircraft in given visibilities will be needed.

Alternatives are: (1) to increase the runway widths and lengths leaving existing flight and guidance criteria fixed; or (2) to reconfigure the radio-guidance criteria to accommodate more fully the large sluggish aircraft on existing runways. Existing documentation of ILS errors when considered on a basis commensurate with the fatal nature of instrument landing errors (3 sigma) suggests that even CAT II--the case of 1200 feet of visibility and a decision to land or not to land occurring no lower than 100 feet (after visual ground contact)--may need re-examination.* With

* "Criteria for Radio Guidance and Flight Errors as They Affect the Safety of CAT II Landing Operations," presented at the 20th Annual International Air Safety Seminar of the Flight Safety Foundation, 4-7 Dec., 1967, Williamsburg, Va., U.S.A.

jumbo jets the concept of all wheels within the runway width at threshold is reflected much further out into the approach zone than in the past, since the ability to correct any flight, piloting, or radio errors accumulated during the non-visual portion of the landing approach will be severely limited.

Currently recognized faults of the ICAO (standard) ILS will be under further attack in this period. Course bends due to reflections from fixed objects is one of many that needs attention. The motion of large aircraft landing or taxiing on the landing runway can also create oscillatory course shifts at a slow rate that would be disturbing to all approaching or about-to-land aircraft. Air traffic flow may be limited in CAT II below CAT I landing rates for these reasons. The ability to monitor the localizer course at the runway threshold is critical to CAT II since the pilot will have but 2 to 3 seconds for his decision. Threshold monitoring needs a solution that can tolerate the aforementioned phenomena. Although some half dozen limitations of the ILS have been quantified by ICAO, such as course bends and width, monitoring, airborne receiver errors, display and coupling errors, there are similar flight errors not yet similarly quantified. Human piloting or autopilot limits in following a given course under conditions of wind shear, heading, decrab, and sluggish response of the aircraft require quantification. One cannot merely hope all these complex variables will always add up to a successful landing without measuring each and finding a means to statistically treat them singly and totally so that safe landings are assured by the standards in all cases. Overall statistical treatment of the many individually quantified errors cannot indicate, even one case in a million, any wheel not being over the paved surface at the runway threshold. Permitting an increase in missed approaches in going to CAT II from CAT I would be questionable risk management. Economic penalties of missed approaches and restricted landing rates due to surface aircraft adversely affecting the landing beam signals are not likely to be acceptable by the mid-70's. Full justification for introducing a new system during the last half of the decade will then be evident.

Visibility and wind shear measured at several points including the 100-foot height and throughout the roll-out will be essential for CAT II and III. Somehow the regulatory authority must be assured of adequate visibility and perhaps must even guarantee such to the pilot before he commits himself at a specific critical height below which he cannot safely, and repeatedly under all conditions, extricate himself and his aircraft.

New court actions in any additional low visibility accidents, particularly if they involve conditions of CAT II, will probably result in the further legal or regulatory restrictions and the need for full quantification and positive assurances in such matters. All such parameters should add up statistically to a safe operation before further visibility reductions are authorized. Flight test and simulator validated information on each of the respective errors involved--radio, flight, visual, winds, etc.--will be demanded. A single jumbo jet landing accident in CAT II will obviously raise all these issues if they are not adequately clarified and assured before such an occurrance. No overall "total-system" assessment has as yet been made for CAT II or III operations of these new aircraft.

Landing criteria of the 1970-1980 period must recognize the elongation and flaring of the longitudinal flight path of a large jet transport, otherwise sink rates will be too high. This path elongation, from what is typically the geometric origin of a shallow glide angle, is some 1000 to 2000 feet, depending upon the maneuvering limits, flight dynamics, and speed of the jet aircraft. It is not accounted for with all types of aircraft in the existing landing criteria. The assumption that the aircraft touches down about 1000 to 1200 feet from threshold cannot be realized with the locations of the straight line glide path.

Constraining all aircraft to a single, straight-line, glide path, directed at a single "aiming point" will become increasingly unrealistic in the 1970 decade. Various means for variable aiming points and positive flare-path guidance will be investigated, and probably near the middle of this time period the most acceptable one will be adopted.

This generally infers that a new landing system will be needed. Already some technical committees are examining the potential characteristics of such a system. The landing parameters of a DC-3 are so different from those of a 747 that it is likely the single straight-line glide path will be abandoned and a new concept of flexible, but safe, aiming points established. A safe touchdown will be ensured at reasonable sink rates, and at the desired location--still probably about 1000 to 1200 feet inside the runway threshold.

Roll-out guidance and surface surveillance and control will become increasingly important in the 1970-1980 time period since the poor visibility that will be authorized even in CAT II and the more difficult man-machine relationships of the large, long-bodied jets will make it necessary to complement visual guidance with electronic aids for precise centerline guidance and precise heading relative to the runway centerline in CAT III. A precise decrab maneuver must assume the aircraft is decrabbed in cross wind at the precise moment with the resultant heading precisely determined with respect to runway centerline direction. Errors less than one degree for decrabbing large, long-bodied aircraft will probably be needed by 1975 to realize any benefits of the CAT III potential.

In summary, progress in All Weather landing of Air Transport aircraft will be slow and painfully realized during this period down to perhaps the CAT IIIB level by 1980. The close association of acceptable values of the many system errors with the overall safety record of Air Transport will become far more important than it is now considered. Quantitatively established limits of some 10 to 15 error sources must be established, controlled and essentially guaranteed the pilot who attempts the landing of a jumbo jet at the visibility of CAT II and III. Although not clearly evident in form or timing, a new landing system will evolve.

Hopefully, with enough effort this "low-visibility-barrier" will be broken by the beginning of the 1980's. Its relationship to the economics of the Air Transport industry will also be more fully appreciated. It is likely that what seemed a few years ago a prohibitive cost to engineer and install a new landing system will, by 1975, appear as a relatively reasonable and accepted cost. The investment in the worldwide fleet of Air Transport aircraft may then total some fifty billion dollars. The one billion that may be needed for a true (nearly) "All-Weather" landing system will probably be fully committed by the end of this time period. Its full effectiveness, however, will not be realized until about the middle of the next decade, due to the usual slow process in this field and its critical safety aspects.

DEVICES IN AIRCRAFT

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From the earliest days of flying it has been necessary to provide gadgets or devices to help the pilot. In the first instance these were obvious and straightforward aids such as compasses and airspeed indicators. As time has gone on, and at an increasing rate, other more elaborate devices have been found necessary. These modern devices, for instance, yaw dampers and stick pushers, augment the natural qualities of the aircraft and help the pilot in the task of control. Autoland marks a further stage and virtually replaces the pilot for a limited phase of the flight.

This trend is likely to grow. We expect aircraft to fly faster, carry bigger loads, fly in all weathers, and do so more safely. These demands lead to a man-machine combination which puts excessive demands on the man. The pilot's strength is insufficient and his ability to think and act quickly enough is becoming inadequate.

Whether we like it or not, and many engineers and most pilots do not like it, the 1970's are likely to be the age of the device. Pilots dislike gadgets for very good reasons. They fear their unreliability. They are inclined not to work when wanted, and sometimes tend to operate when they should not.

Thus a curious situation lies ahead. The human pilot needs gadgets which supplement his strength, or "think" and act more quickly than he can himself. But the gadgets must offer reliability of the same order as the human being. A human pilot rarely goes to sleep, or runs amok when flying, which electrical and mechanical devices tend to do. In other words the human brain and body may be incapable of meeting extreme demands, and yet within their limitations human beings are reliable and pretty consistent.

The lesson from this is surely that there will need to be a great effort to secure an extraordinarily high level of reliability in the various gadgets and devices used. The human pilot must be convinced that he is relinquishing his authority to a worthy successor. It is interesting comment that in the first space flights, the astronauts had no control, the judgement necessary being considered too difficult. Now astronauts have limited control authority. The aeronautical and astronautical practices began at opposite extremes, and are now coming together.

The search for supreme reliability will be a major problem in the next decade. The risks of failure to function in flight can be reduced by multiplex systems, but if this is carried to extremes, increased maintenance is involved. The basic reliability of the individual building blocks will demand attention. Proof of reliability will also pose problems. We shall be seeking evidence that total failure is highly improbable - perhaps once in 10 million flights - on the basis of test evidence the duration of which is relatively short - perhaps 100's or 1,000's of flights. The design and interpretation of proving tests will clearly require attention.

If we accept that the pilot's function as a control authority will gradually be replaced by automatic means, the pilot will more and more have a monitoring function. His flying skill will tend to become rusty with disuse. Yet in the event of the rare failure of automatics, his skill will be important. So again the question will be posed as to how to retain skills which are only called upon very infrequently.

AIRLINE TRAINING IN THE 1970'S

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With the advent of third and fourth generation turbine-powered aircraft during the 1970's, the industry will be faced with unparalleled challenges in the field of crew training. There is no question that the operating parameters of these aircraft will require new and imaginative concepts in training methodology and training aids.

A similar awareness of impending changes to operations and training technology existed in the 1950's when preparations were being made to replace piston aircraft with the larger, faster turbine-powered equipment. Utilizing the knowledge gained through military operations and information provided by aircraft manufacturers, extensive programs were developed to insure safe, timely and reliable performance for the new generation aircraft. The success of those efforts can be measured by the world-wide acceptance of airline travel.

As experience increased, new insights into jet aircraft operating characteristics were discovered. In most cases, this was characterized by a greater depth of knowledge, rather than unanticipated discoveries. Typical of these factors were the effect of turbulence penetration speeds on aircraft controllability; the relationship of body rotation and engine power in control of descent rates on approach; the importance of touch-down targets for precision landings; tire hydroplaning; controllability during reversing, particularly with aft-mounted engines; spin-up characteristics of fan-jet engines; tire cornering phenomena with the concurrent use of brakes. Each of these factors was encountered in actual operations and corresponding adjustments were made in the training curricula to insure effective transferal of information to the flight crews. At the same time, it was established that, due to the improved reliability and reserve power of the turbine engine, the need for certain historically accepted training maneuvers was reduced. An example of this type of maneuver was the repetitive practicing of two-engine-out approaches.

The experience gained in coping with these operational problems highlights the need for attention to operating characteristics being built into future generations of jet aircraft. These aircraft will be larger, faster, and more technically sophisticated than current fleets. Some of them will operate at altitudes not previously used for commercial operations. The rapidly expanding volume of air traffic, with resultant air space and airport congestion, will necessitate further refined standards of flight crew proficiency and discipline in order to insure attainment of industry flight safety goals. One of the most important factors in reaching these goals will be the development of advanced training programs that will achieve higher levels of individual crew member proficiency at an economically feasible cost.

Because of the extensive financial outlay necessary to acquire and operate these new aircraft, it will be imperative that training curricula in the future be based on the most modern and efficient training technology. This technology must include scientific consideration of each of the elements involved in the training process. These elements include:

1. The human factors inherent in acclimating man to the complex machine.
2. The structure of the training process in terms of logical progression in the acquisition of knowledge and skills.
3. The timely utilization of training devices to build confidence and demonstrate attained proficiency.
4. The integration of all training phases into a continuous goal-oriented program.

The accomplishment of this task will require the combined resources of all elements of the industry, including the manufacturers, government agencies, and air carriers. Timely analysis of all design parameters in the aircraft must be accomplished so as to anticipate problem areas. Past experience must be used as a guide in this regard to eliminate unanticipated negative operating factors. Manufacturers' flight test programs must be structured to insure evaluation of aircraft performance characteristics under typical airline operating conditions. Aircraft performance data must be made available to simulator manufacturers in a timely manner so as to enable individual airline use of simulators in advance of aircraft delivery. In this manner, experience with performance characteristics may be acquired by airline training personnel before actual flight operations commence. Such a program will enhance early detection of operating problems and the establishment of appropriate procedural safeguards.

One of the most pressing problems to be resolved in applying advanced training technology is the role of the actual aircraft in the training program. All experienced training personnel in the industry concur that the cost of extensive flight transition training programs in the aircraft will be prohibitive. This, along with increasing airport and air space congestion, makes necessary the development of alternate training methods which will minimize or eliminate that phase of training. Extensive industry experience with flight simulation establishes that this medium is capable of the task. Many advances in the state-of-the-art of flight simulation are already under development. Innovations such as motion systems with six degrees of freedom and simulator visual attachments with near "real-life" presentations, including full circling capability, will assure almost complete transfer of learning from the simulator to the aircraft. Consequently, these devices will be able to assume an increasingly greater portion of the training task. Validation of that concept is anticipated within the next eighteen months when the first Boeing 747 training program will be implemented.

The potential of small jet trainers and variable stability jet trainers should not be ignored.

In addition to the basic capability of the simulation equipment, advanced techniques in software and programming will be required. This involves the development of integrated programs including ground technical instruction, the application of technical knowledge in part-task trainers, and the initial line assignment phase of the training program. Historically, many training programs have been based on sharp divisions between successive phases of training, with ground school being accomplished in the conventional classroom environment, accommodating fifteen to twenty trainees simultaneously. Only at the completion of this phase have the trainees proceeded to demonstrate knowledge achieved in procedures trainers and simulators. Subsequently, when the basic technique of flying the aircraft to prescribed standards had been achieved, the trainee proceeded to the line assignment phase for observation under scheduled flight conditions.

This concept of training will not necessarily be consistent with the needs of the trainees in the new generations of aircraft. For maximum efficiency, it will be desirable to convert from group instruction in ground school to more individual learning procedures. Evaluation of each individual's training needs will be required before commencement of training, and programs must be tailored to those needs. In this way, each individual will proceed through training at his optimum rate and will most efficiently and effectively learn the techniques and responsibilities of his duties. This technique will be applicable throughout the training process through incorporation of task-tailored curricula in part-task trainers, flight simulators, and in the aircraft during the initial line assignment period.

Knowledge gained during the present decade reveals conclusively that effective, advanced training equipment and techniques are necessary to attain maximum operational safety and reliability. This, then, must be the concept used as the foundation for the development of even more refined training methods to meet the needs of the future. Extensive research and development by manufacturers and educational specialists, including airline training personnel, must continue so as to anticipate the operational and training implications of the advanced subsonic and supersonic transports. The result will be a training process which will be as new as the aircraft itself.

This represents the basic challenge facing flight training personnel in the 1970's.

A SYSTEMS APPROACH TO SAFETY -- HOW AND BY WHOM

Maj. Gen. Clifton von Kann*

The thoughts outlined below are limited to a purview of U. S. airline safety; however, the results might be extrapolated to other segments of aviation. In view of the high percentage and varied nature of the world's civil air transport operations conducted by U. S. airlines, these observations may be of interest to airlines of other nations.

From the historical standpoint it would seem that things are going well. (1) Airline management is preoccupied with safety, because it knows that safety is the most important element in airline operation and that nothing worse than an accident can occur. (2) Airline accident rates are comparable to the safest ground forms of public transportation. (3) The likelihood of an airline passenger failing to safely complete his trip is negligible. (4) The safety regulation and investigative functions are firmly established within the government and are carried out by well-qualified and highly motivated people, both in the Federal Aviation Administration and the National Transportation Safety Board.

So it would seem that airline safety performance and its regulation represents a model system that could well be copied by other transport modes.

If this is true, and in general it is, what then is the problem? The problem is not so much whether the present situation is good, but whether the future will bring comparable or even better results.

Looking ahead, current forecasts for all forms of civil aviation are well known; there is no doubt that the numbers of aircraft and the resulting exposure will continue to increase; it is also known that the government investment in aviation safety has been declining throughout the 60's. Where these diverse trends will lead cannot easily be determined.

Also known is the increasing government effort to shift the burden of financing the airways to the users, notwithstanding the obvious public interest benefit of a safe and efficient civil aviation infrastructure.

We also know that in the democratic process, whatever the government does, it does slowly. Only in a crisis is rapid action taken; in those situations the prescribed remedy sometimes misses the real problem. As an example, the recently directed 250 knot speed restriction at and below 10,000 feet was alleged to increase safety on congested airways. In reality it was a patchwork solution to the real problem which was, and is, lack of sufficient, modern airways facilities and equipment to handle the high speed flow of modern jet traffic with increased efficiency and safety. A more systematic and timely approach would have identified the problem in advance and provided a more rational solution.

Further, governmental action must be subjected to the cost/benefit test -- a dubious methodology if a systems approach is not made the basis for the cost/benefit analysis. If the trend toward the cost/benefit test in safety regulation continues, a systems approach seems essential. Regulations must be economically viable, assuming a favorable accident rate exists, lest there be no industry to regulate.

So no matter how well we have done in the past what may lie ahead is less reassuring.

It is appropriate at this point to indicate what is meant by the systems safety approach. There are many definitions. Ours is a method of analysis which: (1) addresses itself to all factors bearing on airline safety -- using all available information -- statistical and otherwise; (2) seeks to isolate and establish basic causes of accidents; and (3) defines action programs to attack these causes. Such an approach also weighs costs of alternative action programs to insure that investment in safety has maximum impact and is not dribbled away in fringe efforts, which may not even be mutually consistent. In the course of the statistical analysis risk probabilities are identified and assessed, so the selection of action programs becomes, in effect, an exercise in risk management. The ultimate goal of the systems approach and risk management is a method of accident/incident predictability.

Any concept of a systems approach to safety must contain all or nearly all of these elements. The various trends affecting airline operations make it inevitable that the systems approach be used to insure that airliners are operated safely and reliably, as well as economically.

Actually, the Air Transport Association has started down this road. It is now in the process of a first cycle examination of aircraft accident statistics recognizing that this is a process which must be recycled many times and in ever increasing depth before true causes begin to emerge. Further, feasible methods of establishing an industry-wide safety data bank are being explored since data is the essence of scientific methodology. An attempt is underway to isolate gross problem areas, such as approach and landing accidents; for the statistically significant areas can be investigated concurrently with the establishment of more refined data systems.

In this respect the National Transportation Safety Board has considerable capability in statistical services and is prepared to support airline efforts to improve safety data systems. The FAA also has much statistical data at its disposal, although this is utilized primarily for internal purposes.

With both industry and the government showing increasing interest in statistical data, the question arises: if a systems approach to safety is to be pursued, who should be in charge of the undertaking?

There are two possibilities in the government-- The Federal Aviation Administration and the National Transportation Safety Board. The FAA has access to a great deal of important information; it has expertise among its personnel; and it has the mission of insuring public safety. However, there are formidable pressures upon FAA which work against an effective systems approach to increased safety in aviation. The Administrator himself is under constand pressure from the public and Congress and under constraints imposed by the Administration. Then there is the fact that any essentially bureaucratic organization tends to defend the past and to provide its head with 100% insurance against any contingency. Lastly, through the unpredictable cyclic rise and fall of government annual budgeting any systematic long range financing effort to meet planned needs for growth and modernization of the National Airspace System is very difficult, if not impossible, to sustain.

Does the National Transportation Safety Board offer a better prospect of successfully applying a systems approach to civil aviation safety? It does not because it is too limited by charter and by organization, and too remote from day-to-day civil aviation operations to be the spearhead for aviation systems safety analysis. Its major job of accident investigation and determination it does very well; but its role in accident prevention as part of a system effort is not clear by charter and practice.

The Department of Transportation has been excluded for consideration as the government agency for the planning and conduct of such effort because:

a. by charter it is a policy organization;

b. it is only one year old and still in the painful process of reorganizing and consolidating its myriad highway, rail, marine, aviation and its newly assigned urban mass transportation responsibilities;

c. any integrated transportation systems safety approach is several years away. Meanwhile, the aviation systems safety approach, already late, cannot wait.

If the government is not now constituted to apply the systems approach, what about the airline industry itself? While there are superficial opinions that the U. S. air transport industry is motivated more by economics than by safety, a penetrating look shows this is not so. The one thing the airlines can least afford is to have an accident. The accident potential in the loss of one new third generation jet like the B-747 is estimated by insurance underwriters to be between 100 - 150 million dollars. These are high stakes; thus the identification by airlines of all hazards and the systematic reduction of risks is more important than ever before. Only by providing the highest possible standards of public safety can the airlines have a sound, economic base for survival and continued growth.

The airlines, whose continued existence depend upon the support of an increasing segment of the travelling public, have strong convictions on the need for such a program. Airline management is the only place where there is full and detailed knowledge of operational requirements and the environment in which airlines are operated. This knowledge includes crew training and performance, equipment, working conditions; all supported by a wealth of factual data. Where appropriate much of this knowledge and experience is reflected in both FAA engineering and operational regulations and in manufacturer designs of safer aircraft. The airlines, FAA, and manufacturers are part of a daily information feedback system. This keeps the principals informed; and by a process of design, operational and regulatory evolution, it improves the overall safety of our transport aircraft. At various times each of the principals have been innovators of new operational procedures or hardware systems which have collectively served the goal of improved safety. At other times there has been disagreement on issues within and outside the air transport industry; but the general trend, as evidenced by the U. S. record, has been one of steady, positive improvement.

The U. S. airlines, as a profit-oriented business, have fiscal constraints like any other capitalized business. Management must weigh all alternative courses of action using the detailed operational knowledge available so that maximum results can be purchased for the safety dollars available. The cost/benefit approach must of necessity be used by top management in assessing causes, remedies, and tradeoffs; and in reaching decisions on the best safety programs. These systems oriented safety analysis methods provide the best basis for risk management decisions.

But there is a final and most important caveat. Decisions bearing on safety must be made at the highest management level. The systems approach is a generalist approach because it seeks to consider all facets. It tries to identify all hazards, determine which must be eliminated, which can be accepted, and what research is needed to reduce them. This means that decisions are difficult and complex, involving conflicting viewpoints and the vision to accept short term costs for long term gains. Only the best of executive talent has the judgment and the statesmanship to make the right safety decisions consistently; and this talent is most likely to be found in the chief operating executive.

The increasing cost of accidents, the expected growth in civil aviation traffic, the history of the past and the relative static funding and staffing of U. S. government agencies indicates the need for close participation by industry in the formulation of safety requirements through a well developed systems approach. Thus every facet of interest and every discipline becomes involved on an orderly basis before rather than after the act. Only in this way can we do away with crisis management of risk.

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THE DIGITAL COMPUTER FOR 1970-1980 AIR SAFETY

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Use of the digital computer permeates all air transport related fields. As in other industries it was first used in the areas of accounting, payroll, inventory and the like. The most widely publicized, and the computer application most familar to the traveling public, is in passenger reservations. Computers will have a growing impact on the safety of air transportation in the decade beginning in 1970.

The digital computer will continue to be a significant factor in many of the solutions to problems of design, construction, testing, operation and maintenance of aircraft. The computer's proven characteristics of speed and reliability, precision and accuracy, and the versatility for application in complex systems will offer the possibility for such solutions at a level of safety not otherwise available because the alternatives would be too large, too heavy or too expensive.

Airborne Computers

The airborne digital computer has the potential to monitor, record, check, diagnose, control, navigate and report aircraft flight progress in ways limited only by the restraints of our judgement as to the appropriate balance between man and machine that should apply in any of the integrated systems that make up the total aircraft capability.

It is clear that in many areas safety can be greatly enhanced by the ability to read, record, manipulate and analyze information more rapidly and efficiently. The application of a digital computer (brain amplifier) to systems monitoring, fault diagnosis, aircraft systems management, air data processing, flight director information display, enroute navigation, position reporting and terminal area guidance, can contribute to safety when properly used to present clear and concise information to flight crews in such a way as to stimulate prompt and reasonable response when crew action and/or reaction is required.

The intergrated data systems now coming into use to provide airborne monitoring and recording of selected aircraft component or system conditions will lead to future developments contributing greatly to flight safety. Such data systems will display pertinent information for optimizing the mode of operation and to describe the status of equipment which is abnormal. These data systems will also be evolved to permit air to ground transmission of significant information useable to judge the requirement for non-scheduled replacement or repair of components.

Airborne data systems are already at work on some aircraft monitoring aircraft performance, engine performance and aircraft systems. The observed data may be analyzed for significant trends indicating incipient problems needing attention. A new application with promise for improved safety is computer surveillance of fire warning system signals, and their correlation with other data, to improve reliability and reduce the incidence of false warning.

The computer's ability to assimilate and process information from Inertial, Doppler, Loran and VOR/DME sources and provide timely position and progress information offers the potential for improved safety by reducing the error size in position fixing. The trend of development looks for improved navigation systems to provide a high degree of accuracy and reliability in establishing the primary fix data on which free trackage and area navigation can be accomplished. Such airborne systems will allow greater freedom to fly directly between origin and destination points without the restraint of specific air routes. The wider use of area navigation techniques will increase the effective capacity of airways and provide a significant means to accommodate growing traffic density on many routes without reducing separation standards or the level of safety. Ultimately the separation standards will be safely reduced, and especially on ocean routes computer processed sattelite data will increase traffic capacity and at the same time provide greater safety.

The struggle for reliability will continue. The need for redundancy and "back-up" to prevent deterioration of existing levels of safety will provide a brake to the speed and the areas in which the digital computer will automate functions which more and more remove the pilot from the "loop". Because the digital computer is versatile, it will be used in many applications. Because it can be reprogrammed with relative ease its application can be evolved with the satisfaction of a desired level of safety in each step.

Ground Based Computers

The ground based digital computer will improve its contribution to safety in air transportation in meteorological data processing, pre-flight planning and flight following, air traffic control and in many other areas where its use is already evident.

The rapidly expanding applications for "on-line" computer/communications systems operating in "real-time" bring a capability for the speedy and precise handling of prodigious amounts of information. Since, in a sense, safety is timely information, the digital computer makes timely and useful more information than possible by any other means.

In this context the principle function of ground based computer systems is to probe, measure, process and forecast the air transport environment. It is so for the systems applied to world-wide meteorological data collection, analysis and prognostication. It is so for systems applied to route optimization, performance analysis, flight planning and flight following, and it is for for systems applied to the identification, monitoring and control of aircraft in flight.

Computer aided systems for processing meteorological data are increasing in their use for the planning and support of transport aircraft operations. Today the time interval between observation of data and the accomplishment of a flight planned on the basis of such observations is as much as 30 hours. This interval is being reduced to as little as 12 hours where computer forecasting and flight planning systems are in use. Utilization of the full potential for computer/communications systems can bring this interval down to a real-time cycle of merely minutes with a commensurate improvement of the timeliness of information and the level of safety.

The pre-flight planning function which establishes the desired route, flight levels, cruising speed, expected fuel consumption, alternate airports, fuel reserve, and take-off and landing weight limitations applicable to a flight can also be improved in timeliness by the modern computer/communications system. Contributions to safety can be made in this area not only as the result of speed but from the wider scope of varibles which can be explored, and from the elimination of exposure to manual processing errors. And by freeing the time of dispatchers and pilots to provide a higher standard of surveillance and control of operations.

The automation of terminal area traffic control proceeds on a direction and at a pace hardly satisfactory to all, but offering promise for contributions to improved safety. The addition of alphanumeric identity, altitude read-out and computed ground speed for aircraft targets on radar displays now coming into use and the potential for approach sequencing, integration of display, and other features will provide some basis for holding the line on acceptable levels of safety as the number and severity of high density traffic areas increase. And the human controller will be freer to provide a higher standard of surveillance and safety.

The computer appears to have a great potential for expanding the scope of accident investigation. The ability to store and selectively examine large masses of historic data can lead to the identification of analagous situations and elusive clues from other incidents which may have a bearing on the cause of the subject investigation.

This same computer ability to provide instant recall of selected data from mass storage will be useful in exploring the operations and maintenance history of aircraft. This ability is currently in use by the U. S. Coast Guard to provide an instant display of all surface vessels currently located in proximity to the site of a possible emergency.

Computers are also proving to be invaluable in preparing for the introduction of new aircraft by simulating their operations prior to delivery. Simulation of enviromental factors such as meteorology, navigation requirements, and air traffic will illuminate the areas for attention to maintain or improve existing levels of safety.

A fast burgeoning area which shows a strong trend for increased contribution to flight safety in the future is flight simulation and training in systems based on the use of high speed digital computers. The broadening capability of new digital computer driven flight simulators provides a potential for greater scope and realism in flight crew training. The role of the simulator can be expanded to that of an advanced "teaching machine" to improve rather than merely check for a level of proficiency with each exposure.

The computer will continue to establish itself in air transportation as the unique solution which can reduce operating costs and at the same time provide greater safety.

THE COCKPIT

Robert Buck
Airline Pilot

The certification of aircraft and contributions by test pilots do not reflect sufficient realism of the day by day problems faced by the working airline pilot operating on rigorous schedules.

The cockpit safety problems of today will be aggravated by the increase in traffic, speed and aircraft size in the 1970 - 80 period unless corrective actions are taken. Not only design but route assignment compose the problems. Admittedly many of these observations are subjective.

Some of the problems may find solution, but the slow progress of the past does not create confidence that the 70 - 80 decade will show dramatic change.

Today, after almost three decades of modern air transport, cockpit stress results from the fact that airplanes still burn after they crash, they run into each other, people sustain crash injuries that could have been prevented, and humans are given aircraft to operate that invite human error.

In the cockpit, fatigue still effects safety. It could be alleviated by tailoring the hours to the specific demands of the route and its associated infrastructure. The cockpit environment needs improvement. Relief is needed from the glare caused by high altitude flight. Lighting is inadequate to illuminate the work, excessive reflection in windshields has not improved since the DC-3. Cockpit seats are uncomfortable, originality is lacking in their design. Has anyone ever considered a partial prone position, for example?

The mass of communications between cockpit and ground should be reevaluated and reduced. In its current primitive form it requires a crew member to fumble with a microphone, make numerous changes in frequencies, take notes, receive and transmit at a rapid pace. Will this be permitted to grow with traffic? Mistakes are easily made and not easily noticed. A communications system which transmits information through signal lights or automatic written means to the aircraft--and the communications kept to a minimum--would appreciably increase safety by reducing distraction especially in congested areas or during emergencies.

The picture of one crew member reading a check list while the other looks at the items to be checked reduces attention to search for other aircraft and again distracts from efficiency in flying the aircraft. The long check procedures must be reduced, controls should be designed so they cannot be set improperly, with only a few simple go-no-go indications required to be checked.

Paper work is voluminous. Hard to read charts are used for navigation, company forms must be filled out. In one case the Doppler deviation is computed by the pilots and entered in three different places in exactly the same manner. Who looks out, and who double checks the other pilot while one is doing all this? Certainly some serious thought can reduce the clerk like cockpit paper work and surely a pictorial display can replace the charts.

A device is long overdue to tell the pilot when he is approaching the altitude he is cleared to or when he is leaving it.

Must we be mentally blocked by the idea that all traffic control must come from radar and the ground via complex, error prone communications? The pilot needs some form of traffic control and collision avoidance display in the cockpit. Would it not be possible to have an aircraft separation indication in the cockpit so that two aircraft could be cleared in the same air space to let them keep their own separation? Surely aircraft crew members and the art of electronics have the competence to do this. Collision avoidance systems appear to be in process. What will delay their implementation?

The aircraft itself does not adapt to the job of traffic control. There is not sufficient speed control by air brakes or other means for the pilot to comply with ATC's needs. The simultaneous management of descent and speed reduction is awkward. This ability must be designed into aircraft. With this is needed a computer to tell the pilot how he can best adjust speed within the time period when called upon to do so.

ATC must be able to tell the crew in advance his altitude, specific route and probable delay. Under the present system long flights carry large fuel loads to fit unknown ATC deviations. But even with excessive fuel loads delays and re-routings sometimes cut deeply into fuel reserves. The present system then becomes a gamble--one that pilots would rather avoid.

Attention needs to be directed to aircraft stability, control and handling characteristics in relation to specific phases of flight. Present jets require control forces that are too high. Their handling qualities are poor where needed most, during take off and landing. They land too fast.

The present method of flying an airplane in the approach area is old fashioned. The idea of pushing the tail down to make the nose go up--the flare--is antiquated when one experiences Direct Lift Control enabling the wing's lifting ability to change instantly without rotating the aircraft. DLC offers precise glide slope control and much improved ability to hit an exact touch down point. It provides protection from sudden deviation in flight path when passing through shear conditions. Aircraft with DLC are more controllable when descending during an instrument approach in the wake of an aircraft just ahead, a point people who wish to jam airplanes close together on a runway often fail to consider or realize.

To reduce crew apprehension, ability to stop aircraft must be accelerated for the 1970 - 80 era. Present runway incidents with their associated delays and hazards should not be tolerated. Runway surfaces, arresting hooks, better brakes, tail parachutes, precise runway braking, friction coefficient information for the pilot and other ideas need to be effectuated, not just discussed. Current attention to runway grooving is a step in the right direction.

Instruments should be improved. Why must glide slope control be a combination of instruments? Is it impossible to put this information in one instrument, with one indication? Why not review the entire panel to see if it is possible to find better instruments for the modern job? Undoubtedly much exploratory research has been done in this area. When will the results be found in the cockpit? Is it an economic problem?

Most frightening to the pilot is fire after crash, even after the most simple and gentle crash. It is a fact, well substantiated by past performance, that emergency evacuation methods do not always perform as intended. Slide chutes do not always work, exits are blocked by fire or damage and humans can be expected to react at their worst during the confusion of a crash with smoke or darkness, or both.

There is no cure for this save one, do not allow the fire to start! Technology promises this, but the aviation community has not yet seemed to realize the importance that must be placed on this problem, the all out effort that must be made. Surely the large aircraft of the immediate future with the potential of hundreds of people being burned to death must not be permitted. Fire prevention is imperative before these aircraft fly! Fire potential produces cockpit stress. The captain bears responsibility for his passengers and crew until they reach their destination safely.

Much effort is being expended to uncover the feasibility of correcting many of the cockpit problems outlined in this brief presentation. Probably the greatest problem is to reduce the time between the solutions and their implementation! Do it before the accident, not after, at possibly greater expense.

THE CONTRIBUTIONS OF HUMAN FACTORS ENGINEERING TO AEROSPACE SAFETY
1970 - 1980

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I. Introduction and Statement of Problem

Accidents have been caused by inadequate attention to well known human factors in detail design of aircraft. This should be corrected for the decades ahead. This brief paper portrays items that deserve particular scrutiny.

A very promising approach for improving efficiency and for preventing accidents in the decade of the 1970's involves the integration of the engineering and biological sciences in the development of machines and equipment. It became apparent during World War II that the results expected from many complex machines operated by men were not being realized. From an engineering point of view the equipment was more accurate, faster, and more durable than previously. However, it failed to perform as well in combat as during the development and acceptance testing phases. Analysis of such failures revealed that the requirements of the machines with regard to sensory discriminations or motor responses often exceeded the capabilities of their human operators. Such a viewpoint implies that the capabilities and limitations of human operators should be fundamental considerations in the design of machines. The development of larger and faster jet aircraft will require even greater attention to such variables.

In the design of displays or instruments, the signals needed to supply the information required by the operator should be based upon an understanding of the sense organs and of the characteristics of human perception. Data on the range of human body size are important for the overall layout, seating, and location of controls. Body sizes may be expected to change somewhat in the years ahead. Information on biomechanics, that is, range, strength and speed of movement, is required for the proper design of controls. Furthermore, the abilities of an operator are not always at a maximum. He may be influenced by fatigue, minor illness, poor motivation, or by noxious features of his environment. (McFarland, 1960.)

A few examples may illustrate this point of view. If an auditory warning signal is to be used to indicate the malfunction of equipment, it would be best to select a frequency band to which the ear is most sensitive, and which lies below the frequencies which older people hear poorly. If muscular "feedback", as well as vision, is important the resistances in a power-steering system should be related to information about human "muscle sense". If two control knobs are located close together on a console they should be designed so that they can be readily differentiated to prevent inadvertent operation of the wrong control. Similarly, the seat provided the operator should be so designed as to ensure maximum comfort and efficiency and to prevent back strain and fatigue. Also in the "Jumbo Jet" the free flow of passenger traffic must meet the requirements of both normal and emergency conditions.

II. The Design of Displays and Controls

A. Design of Displays to Prevent Errors

Accidents, or operational errors, often occur because the man has misinterpreted, or was unable to obtain information from his displays concerning the functioning of the equipment. Displays are usually visual in nature, though they may also be auditory (i.e., warning bell rather than a warning light). In jet aircraft of the future the implications of an error are so great that very precise studies must be made of how much can be automated and how much can be relegated to the pilots. Experiments show that underloading or overloading the operator may increase the tendency to errors.

Any display or indicator, regardless of type, must possess the following basic characteristics if it is to be as nearly foolproof as possible: (1) It can be read quickly and in the manner desired; i.e., as a check, qualitative or quantitative display. (2) It can be read as accurately as is required (and preferably no more accurately). (3) There is no ambiguity or likelihood of gross reading errors. (4) The information is provided in the most immediately useful form and does not require mental translation into other units. (5) Changes in value are easy to detect. (6) It can be easily identified and distinguished from other instruments. (7) The information is as current as possible; i.e., lag is minimized. (8) If inoperative, it either cannot be read or the operator is properly warned. (9) When applicable, the instrument indicates which control to use, and in which direction to use it, when changing its reading. (Baker and Grether, 1963: McFarland, 1946, 1967).

Even experienced operators have difficulties in correctly reading certain types of instruments.

The conventional aircraft altimeter, for example, is equipped with three pointers, each requiring separate interpretation before the pilot can determine his altitude. Errors caused by this type of instrument have been frequently reported by pilots in confidential statements. Misreading of the altimeter has been cited as the cause of aviation accidents. Studies comparing the errors made in reading the old and improved altimeters by both novices and experienced pilots have shown that the new design can be read much faster and with far fewer errors.

It is interesting to note, in regard to check reading a bank of dials, that if the pointers are aligned horizontally the number of dials that can be checked in a given period of time is increased by a factor of eight. Also, alignment of the pointers at the nine o'clock position is better than at the three, twelve, or six o'clock positions. The superiority of the nine o'clock position over six or twelve relates to the fact that the eye can scan much more efficiently in the horizontal dimension than in the vertical dimension.

Even with good vision and excellent lighting, including high contrast between target and background, the size of the target, or pointer, in relation to the overall size of the instrument is important. In one study, it was found that subjects while watching one dial failed to report one-third of the pointer signals. It was noted that the line of sight was directly on the dial at the instant the signal was given. The errors in form identification were clearly related to the width of the visual display in terms of degrees from the fovea (Mackworth, 1967). What better example could be given of "looking without seeing," and in this case, of making an error that was "built into" the design of the instrument?

In modern jet flying there may be unusual environmental stresses due to the intensity of light. For example, the influence of glare in relation to rapid changes in altitude and cloud formation must be anticipated. Flying in very bright sunlight a pilot may descend so rapidly to conditions involving relatively complete darkness that visual adaptation does not occur quickly enough. Although it is reported that take-off and landings speeds might be reduced with future aircraft, the cockpit configurations may place limitations on the pilot's vision, or field of view. Furthermore, the distance travelled in relation to human response times must be kept within the human limitations. These and many other problems must be anticipated and solved with the aid of human factors engineering and sensory physiology.

B. Design of Controls for Operational Efficiency and Safety

The efficiency and effectiveness with which controls can be operated depends upon the extent to which information on the dynamics of human movement, or biomechanics, has been incorporated in their design. This is particularly true whenever controls must be operated at high rates of speed, against large resistances, with great precision, or over long periods of time. Controls should be designed therefore so that rapid, accurate settings can be easily made without error or undue fatigue. The relation of push pull forces to lateral forces at the control wheel deserves strict attention.

Since there is a wide variety of machine controls ranging from the simple on-off action of push buttons the very complex two-dimensional graded effects, advance analysis must be made of the task requirements to determine the suitability of various controls for different purposes. A considerable body of experimental evidence for specific recommendation exists in this area. (Provins, 1965). Some general first principles may be applied to the design of machine controls to eliminate error, accident and inefficiency are as follows:

(1) Determine the best kind of control for a specific task, that is, foot or hand control, stick or wheel, push button or toggle switch.

(2) The direction of control movement should always be in the expected direction, that is, up or clockwise for on, right for movement to the right, and so forth. Also, positioning for maximum force and speed must be considered.

(3) The extent of control movement should never exceed the range of movement of the operator and the amount of resistance should never exceed the abilities of the weakest operator.

(4) The size, shape and orientation of the control should be compatible with maximum operational efficiency and degree of precision required.

(5) Where necessary, controls should be differentiated, as by shape, size, or color, to prevent mistaken or inadvertent operation.

III. The Role of Anthropometry and Biomechanics in the Design of Equipment

One basic approach to safety in man-machine systems relates to the physical characteristics and capabilities of the operator and to the design of his working area. In order to carry out this approach several different types of information are needed; i.e., a description of the task, an understanding of the kinds of equipment that will be used, a description of those who will use the equipment and, finally their biological characteristics.

Static and Dynamic Anthropometric Measurement. Two kinds of body dimensions, static and dynamic are pertinent to human engineering. Static dimensions, taken with the subjects in rigid, standardized positions, are easily obtained and readily applied to equipment design. Dynamic dimensions - those taken at work or in motion - are more difficult to measure. For example, functional arm reach is not a simple derivative of anatomical arm length, but is a resultant of interacting factors as shoulder height and breadth, length of the several segments of the arm and hand, and range of motion at the shoulder, elbow, wrist, and fingers. Functional arm reach, therefore, changes with each position and movement of the body, arm, hand, or fingers. (Damon, Stoudt, and McFarland, 1963, 1966.) Particular attention must be given to the smaller and larger members of each group of operators. Such information will permit the engineer to define the outer limits of the "space envelope" available for both pilots and passengers.

An interesting example of the sometimes critical role that body dimensions can play in accident causation is afforded by a U.S. Navy study that showed that "tall" pilots, i.e., those over six feet, had a significantly higher rate of involvement in jet aircraft accidents that would have been expected on the basis of chance. Similarly, "short" pilots, those below 5'9", had a lower than expected accident rate. (Lodge, 1963) As a result of this situation, a detailed human engineering evaluation of cockpit dimensions was undertaken, with special attention to the distributions of body size of Naval pilots. From this, an "Aircraft Utilization Code" was developed that would permit the assignment of Naval aviators only to aircraft in which they could be safely accommodated in terms of their body dimensions.

Certain kinds of hand controls on automobiles and military equipment have been designed in such a way that although they can be operated perfectly satisfactorily by the ungloved hand, they can only be operated with great difficulty if at all, by those wearing gloves.

IV. Summary

In general, from the standpoint of human engineering, it is essential that the mechanical design of equipment be compatible with the biological and psychological characteristics of the operator. The effectiveness of the man-machine combination can be greatly enhanced by treating the operator and the equipment as a unified system. Thus, the instruments should be considered as extensions of the driver's nervous and perceptive systems, the controls as extensions of the hands and the feet as simple tools. In general, any control difficult to reach or operate, any instrument dial of poor legibility, any seat inducing poor posture or discomfort, or any unnecessary obstruction to vision may contribute directly to an accident.

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MEDICAL ASPECTS OF COMMERCIAL FLIGHT

1970 - 1980

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Writing comments on this subject is like gazing into a crystal ball. We will be commenting about aircraft that have yet to be built or flown. However, the past is prologue in some ways and we can draw on past experience to predict future performance.

1. Ground Support, Community, and Airport Environment Problems

Future fan-turbine engines for newer aircraft, such as the larger tri-jet (Lockheed 1011, Douglas DC-10, and four-engine Boeing 747), will be quieter yet provide greater thrust, and we anticipate no new noise hazard problems which we already have and which we are handling well if ground support personnel will wear hearing conservation devices when needed. Community noise problems can be handled with proper education and toleration. Larger thrust power sources planned for the SuperSonic Transport may need helmet and chest protection for ground support personnel unless "start" can be accomplished in an isolated area to which the aircraft is towed. Lateral noise during the take-off roll may be a problem. Overpressures affecting flight paths due to sonic boom will probably be our greatest obstacle to overcome. Overpressures of 2+ lbs/sq. ft. have been tolerated by some communities with daily exposure over long periods of time causing little or no ill effects. Only time and trial will solve this problem.

2. The Aircraft

1970-1980 will be a period wherein primarily larger aircraft carrying larger loads, both passenger and cargo, flying as conventionally as today's jet, will be the rule. The exception will be the SST--the Concorde, the U. S. Boeing, and possibly the Russian version. Late in this decade there may be an attempt to fly a hypersonic jet at five to seven times the speed of sound by ramjet propulsion, but this is a dream to be realized. Because of world-wide usage, all aircraft will be equipped with non-toxic automatic dispensers of dichlorvos (DDVP) for disinsectization, approved by the World Health Organization.

3. The Crew

No new medical requirements or standards will be needed for the cockpit or cabin crew in the larger sized conventional jet aircraft. The same applies for the SST crew. No increase in cockpit crew is anticipated. Cabin attendant ratio to passenger load will be about 1:25, perhaps 1:30+ in coach configuration. Consideration is being given to below cabin deck cooking and catering facilities done by an in-flight chef, with elevator lift service to the cabin deck for food and drink distribution. This may decrease the number of cabin attendants needed. Because of larger passenger loads more efficiency will be stressed to effect evacuation.

The SST Crew will need added personal protective equipment (pressure vests, etc.) during the research and development phase, but not in the operational aircraft. Radiation monitoring will be a new crew task but will be aided by cockpit instrumentation and radiation monitoring stations world-wide. It is contemplated that the flight plan of each SST trip will be computerized and programmed into the aircraft before take-off. Pre-flight check items and paper work will be computerized and automated. Excessive ozone concentrations no longer seem a problem to both crew and passengers in supersonic flight. This can be controlled by catalytic devices to break up the O_3 molecule in intake air heated during compression.

4. The Passenger

The comfort and safety of the passenger will in many ways be enhanced and in some ways become a problem with the advent of newer aircraft. The enhancement will be manifested in that there will be plenty of room to move about and to attend to personal needs and pleasures. However, plenty of room also means more opportunity to be subject to slips, tripping, and falling. Proper hand rails or other objects to hold onto and compartmentalization can solve this for both passenger and cabin attendant. Because of the larger passenger load, 250-500, safety measures in loading and unloading must be observed. Also because of larger numbers of passengers with no medical selection contemplated over and above what we have now, the probability of acute illness will be increased in flight. The possibility of an unscheduled landing for medical reasons thus increases. To avert this there is a possibility that a registered nurse who can "double" as a cabin attendant supervising some special medical supplies and instruments that could be utilized by a passenger-doctor aboard may be tried initially by some carriers until experience proves whether or not this is feasible. No contemplation is being made by any carrier to have a resident physician aboard. In the event of a landing for medical reasons shortly after take-off, we are assured that even in the SST there would be no problem; no fuel would have to be dumped, and only an "overweight landing" inspection would be necessary.

With reference to pressurization, it will be improved on what we have now in the larger sized jets to come. In the SST it will be absolutely mandatory that there be a "fail-safe" system of pressurization. The PSI to do this will increase from the present 8.0+ to 12.0+ in order to give us a cabin altitude maximum of 7,500 feet with an outside altitude of 70,000 feet. No compromise can be made here because all human life ceases within a few minutes at that outside altitude. Speed at mach 3.0 or thereabouts is not felt or realized by the passenger per se. Small variations in aircraft attitude and direction will however be felt instantaneously and must be reckoned with. Speed again will create one problem and that is travel dysrhythmia or disruption of the physiological time clock in East to West and West to East flights, traversing five time zones or more. North to South and vice versa, when held within three time zones, will be no problem. Those affected most will be the elderly and those with illnesses on timed medication, such as the diabetic and the ulcer patient.

We have ways of combating travel dysrhythmia and the carriers causing this must be honest and forthright with the traveling public and educate them properly. Proper hotel resting and eating facilities with 'round-the-clock food service of multiple choices, i.e., breakfast at dinner time, proper noise and light abatement facilities should be provided.

On very short trips a business man at mach 3 travel could very well suffer no time disruption on East to West and return flights in that he could leave in the early morning, get to where he is going before his local time, and return in time for dinner, having put in a full business day. The boon of decreased <u>travel exposure</u> time will also be felt by both passenger and carrier.

In short, the two great problems of medical concern regarding comfort and safety in the 1970-1980 high density jet and SST will be sonic-boom acceptance in the latter and travel dysrhythmia in both. These are solvable but it will take some doing.

We are not commenting on VTOL aircraft which may become operational in 1970-1980, because they are merely an extension of existing forms of air transportation, namely, helicopter and conventional aircraft.

ENLARGEMENT OF THE AIR-SAFETY STATISTICAL BASE

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I. Introduction

One hears much now about the necessity for cost-effectiveness analyses. At first glance it might appear that such analyses can immediately be applied to air-carrier safety, but unfortunately it is not possible now to do this to a significant extent. The scarcity of air-carrier accidents, a most fortunate fact in all other respects, prohibits detailed analyses of short-term cause-and-effect, especially when restricted to specific aircraft models or procedures or design changes. Yet, such statistical studies must ultimately become the basis for a scientific approach to improving air safety. The alternative can be nothing more than intuitive judgments based upon experience and common-sense. The fact that such non-scientific methods have todate resulted in a vast improvement of air safety compared with several decades ago attests to the essentially good judgment of our aviation administrators and leaders throughout the world. Nevertheless, one should not be content with this approach for the future if more rational methods can be evolved to aid these judgments.

II. Inadequacy of Present Data

Before discussing what is needed for future statistics, I first make some criticisms about the common statistical indices in use now. In the first place, "aircraft-fatal-accidents" or "aircraft-totally-destroyed" should be abandoned as a basic index since each is very much too scarce to permit reliable statistical inference. It becomes less unreliable if one uses "all-aircraft-accidents" for which the sample size of data is much increased. For example, during 3 recent consecutive years, for a certain broad aircraft category, there were 4,3,2 aircraft totally destroyed. Can one therefore reliably conclude that the risk decreased by 2:1 over this period? Certainly not. Probability calculation shows that there was almost a 50:50 chance that the true risk may actually have increased. The sample size is too small for inference. Secondly, present safety rates based upon "passenger-fatalities", in spite of the larger numbers involved, contain more sampling error than the previously mentioned indices because two extra random variables become involved: the capacity of the aircraft, and the passenger load-factor at the time of crash. These are superimposed multiplicatively upon the basic random error in the "fatal-aircraft-accident" sample.

As a point of departure for the statistics to be needed in the 1970's, let us therefore return to the concept of "all-aircraft-accidents". This now gives us as total data for all U.S. commercial air carriers about 70 to 100 data samples per year, and about double this for all ICAO states included. I have tried to show in previous studies(1,2) that meaningful statistical analysis requires that accidents first be divided into 3 seperate phases of flight (takeoff, cruise, and landing), and preferably into 5 phases or more (counting climb and descent as additional phases). It is essential to ascertain for each flight phase whether 2nd generation jets are safer or more dangerous than the 1st generation jets, and more specifically, what the relative safety trends are from year to year for individual aircraft models. In the 1970's it will become all the more important to evaluate the safety of the 3rd generation jumbo jets relative to the earlier models. Now, if we attempt to isolate all these multiple subcategories for the present kind of data we collect, it is obvious that we get only zero, or one, or perhaps two, accidents per subcategory per year. With such inadequate sample sizes, statistical analyses and cost-effectiveness studies are virtually impossible taken over short time intervals of one or two years. Use of standard techniques with Chi-square confidence intervals for Poisson distributions indicates that at least 15 or 20 sample events per year would be required in order to permit reliable detection of, say, a 20% trend within a two-year period.

III. Enlargement of Definition for Data

From all this, one fact is clearly implied: if we want to analyze air-safety data reliably and usefully, it will first be necessary to <u>increase greatly</u> the sample size with a new type of data, perhaps by a factor of 100 or more. The straightforward way to accomplish this is to enlarge the definitional boundaries of the "accident" concept. We will need a carefully formulated set of definitions for a much broader concept of accident, which we may call an "incident" or more generally a "flight disturbance". This would include not only trivial accidents,

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but also near-accidents, malfunctions, errors, and disturbances both technical and operational. By increasing in this way the total sample size from about 200 per year to perhaps 20,000 per year, analysts will be able to apply their techniques to short-term problems with high reliability and usefulness. It is not my intention here to formulate details of definition or organization for a new system internationally for incident reporting. My present purpose is only to emphasize the urgent need for some such scheme to be adopted. Details can always be worked out later -- When there is a Will, there is always a Way!

Objections are often raised that it would be impossible to maintain a reporting procedure for in-flight disturbances which would be complete, uniform, and objective. I believe otherwise. This could be done as soon as all the necessary organizations realize fully that their mutual self-interests require it. It has come to my attention that at least one major airline is now actively developing such a system within its own company. For maximum utility, however, all airlines should contribute into one huge data pool. An international exercise of this scope might ultimately be administered by ICAO, but we need not wait for slowly moving diplomatic formalities to be completed. As an immediate substitute, it might be started soon, administered jointly by the international pilots' organization (I.F.A.L.P.A.) and the international airlines' organization (I.A.T.A.), the former responsible for rigorous enforcement among its own members of complete and objective reporting, and the latter responsible for processing and distribution of the data, together with bona-fide guarantees that no disciplinary measures whatever will be directed against pilots who report, and that individual airlines will be exposed to no adverse publicity. There is already good precedent for cooperative alliance between I.F.A.L.P.A. and I.A.T.A.: for example, while working in recent years with ICAO's North Atlantic Systems Planning Group, I have seen it amply demonstrated that these two organizations are earnestly cooperating to solve technical problems of mutual concern.

I am also aware that I.A.T.A. is now maintaining its own "Incident & Accident Information Exchange Group". Its reports, however, are kept confidential and necessarily emphasize mostly maintenance faults rather than all in-flight disturbances. Likewise, on a vast scale within the U.S., the Federal Aviation Administration has established at Oklahoma City a mandatory reporting operation for both air carriers and general aviation; this involves elaborate data processing and remedial regulations concerning faults discovered during maintenance checks. The benefits of such operations as these are clearly enormous in preventing the occurrence of many in-flight disturbances, incidents, and accidents.

There remains, nevertheless, the need for some reporting procedure for those in-flight disturbances which do occur, which have not been prevented by rectification of maintenance faults. Just such a procedure is, for example, already working successfully in the Swedish Air Force. At the 1967 International Flight Safety Seminar, General Rosenius described(3) a system functioning since 1962, explaining that "The principle of this system is that any disturbance in flight, technical or otherwise, must be reported by the crew". This he calls "the disturbance reporting system". A chief feature of this Swedish system is that it strictly excludes disciplinary action against pilots who file reports.

IV. Conclusion

More rational safety planning for commercial aviation in the 1970's requires adoption of some system to enlarge statistical data to a useable size. Unless this is done, plans for better exploitation of air-safety statistics will remain only wishful thinking. The broadening of the data base will require considerable effort, but it can, and should, be done. Commenting on the need for a better effort in statistical analysis of air safety, my friend Mr. Najeeb Halaby, formerly the Administrator of the U.S. Federal Aviation Administration, recently wrote(4) with his inimitable irony and humor, "The calculus for risk and cost needs exploration and articulation on a level at least as high as for reaction to in-flight television".

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(4) Halaby, N.E. "Comments on Dressler's Safety Paper", Flight Safety Seminar, Madrid, Nov 1966

but also near-accidents, malfunctions, errors, and disturbances both technical and operational. By increasing in this way the total sample size from about 200 per year to perhaps 20,000 per year, analysts will be able to apply their techniques to short-term problems with high reliability and usefulness. It is not my intention here to formulate details of definition or organization for a new system internationally for incident reporting. My present purpose is only to emphasize the urgent need for some such scheme to be adopted. Details can always be worked out later -- When there is a Will, there is always a Way!

Objections are often raised that it would be impossible to maintain a reporting procedure for in-flight disturbances which would be complete, uniform, and objective. I believe otherwise. This could be done as soon as all the necessary organizations realize fully that their mutual self-interests require it. It has come to my attention that at least one major airline is now actively developing such a system within its own company. For maximum utility, however, all airlines should contribute into one huge data pool. An international exercise of this scope might ultimately be administered by ICAO, but we need not wait for slowly moving diplomatic formalities to be completed. As an immediate substitute, it might be started soon, administered jointly by the international pilots' organization (I.F.A.L.P.A.) and the international airlines' organization (I.A.T.A.), the former responsible for rigorous enforcement among its own members of complete and objective reporting, and the latter responsible for processing and distribution of the data, together with bona-fide guarantees that no disciplinary measures whatever will be directed against pilots who report, and that individual airlines will be exposed to no adverse publicity. There is already good precedent for cooperative alliance between I.F.A.L.P.A. and I.A.T.A.: for example, while working in recent years with ICAO's North Atlantic Systems Planning Group, I have seen it amply demonstrated that these two organizations are earnestly cooperating to solve technical problems of mutual concern.

I am also aware that I.A.T.A. is now maintaining its own "Incident & Accident Information Exchange Group". Its reports, however, are kept confidential and necessarily emphasize mostly maintenance faults rather than all in-flight disturbances. Likewise, on a vast scale within the U.S., the Federal Aviation Administration has established at Oklahoma City a mandatory reporting operation for both air carriers and general aviation; this involves elaborate data processing and remedial regulations concerning faults discovered during maintenance checks. The benefits of such operations as these are clearly enormous in preventing the occurrence of many in-flight disturbances, incidents, and accidents.

There remains, nevertheless, the need for some reporting procedure for those in-flight disturbances which do occur, which have not been prevented by rectification of maintenance faults. Just such a procedure is, for example, already working successfully in the Swedish Air Force. At the 1967 International Flight Safety Seminar, General Rosenius described[3] a system functioning since 1962, explaining that "The principle of this system is that any disturbance in flight, technical or otherwise, must be reported by the crew". This he calls "the disturbance reporting system". A chief feature of this Swedish system is that it strictly excludes disciplinary action against pilots who file reports.

IV. Conclusion

More rational safety planning for commercial aviation in the 1970's requires adoption of some system to enlarge statistical data to a useable size. Unless this is done, plans for better exploitation of air-safety statistics will remain only wishful thinking. The broadening of the data base will require considerable effort, but it can, and should, be done. Commenting on the need for a better effort in statistical analysis of air safety, my friend Mr. Najeeb Halaby, formerly the Administrator of the U.S. Federal Aviation Administration, recently wrote[4] with his inimitable irony and humor, "The calculus for risk and cost needs exploration and articulation on a level at least as high as for reaction to in-flight television".

References

(1) Dressler, R.F. "New Approach to Air Safety Statistics", Journal of Aircraft, July-Aug 1967, New York

(2) Dressler, R.F. "Landing Speed and Accident Correlation", Air University Review, Maxwell AFB, to appear

(3) Rosenius, General "New Deal- Discovering & Preventing Accident Risks", 1967 Flight Safety Seminar, Flight Safety Foundation, Arlington, Va.

(4) Halaby, N.E. "Comments on Dressler's Safety Paper", Flight Safety Seminar, Madrid, Nov 1966