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DOCUMENT IDENTIFICATION

2 July 81

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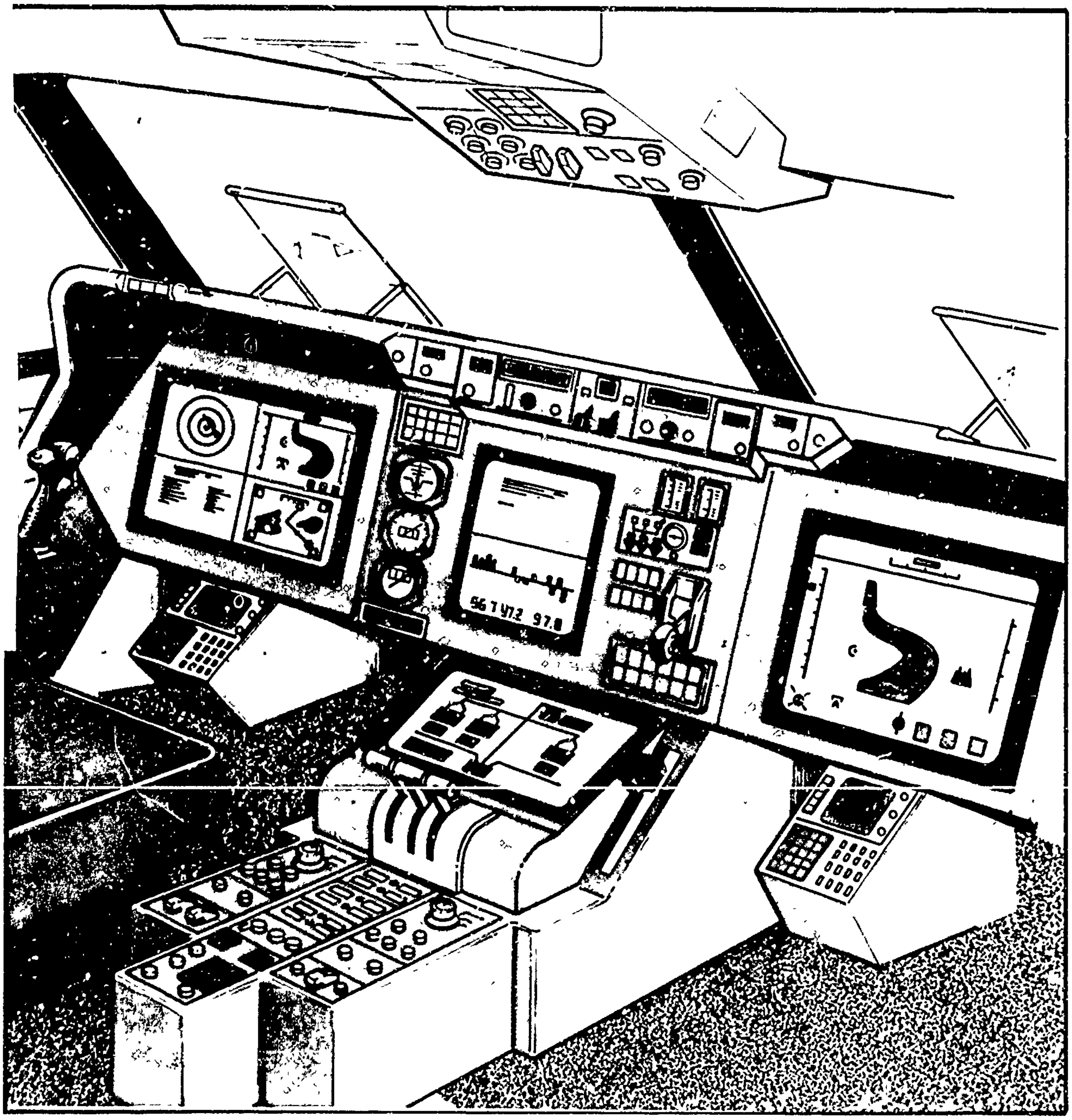
Report of The President's Task Force on Aircraft Crew Complement



July 2, 1981

Technical Report Documentation Pag

1. Report No.	2. Government Accession No	3. Recipient's Catalog No
4. Title and Subtitle Report of the President's Task Force on Aircraft Crew Complement.		5. Report Date July 1981
		6 Performing Organization Code
7. Author's) Dr. John L. McLucas, Chairman. Mr. Fred J. Drinkwater, III. Howard W. Leaf, Lt. Gen., USAF.		8 Performing Organization Report No
9. Performing Organization Name and Address President's Task Force 400 - 7th Street, S. W. Washington, D. C. 20590		10 Work Unit No (TRAIS)
		11 Contract or Grant No
12. Sponsoring Agency Name and Address		13. Type of Report and Period Covered
		14 Sponsoring Agency Code
15 Supplementary Notes		

16 Abstract

The President's Task Force on Aircraft Crew Complement: (1) Reviewed the August 1980 decision by the Federal Aviation Administration to certify the McDonnell Douglas DC-9-80 aircraft for operation by a minimum of two persons; and (2) made recommendations concerning the use of two-member crews in the proposed Boeing 757 and 767 and other "new generation" commercial jet aircraft.

Principal conclusions of the Task Force are: Operation of the DC-9-80 by a crew of two is safe and the FAA's certification of the DC-9-80 for operation by a minimum crew of two was proper and in compliance with the Federal Aviation Act.

17. Key Words	18. Distribution Statement
Crew complement; Safety; Aircrews; DC-9-80; B-757; FAA.	Document is available to the U. S. public through the National Technical Information Service, Springfield, Virginia 22161

19 Security Classif (of this report)	20. Security Classif (of this page)	21. No of Pages	22 Price
Unclassified	Unclassified	103	

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THE PRESIDENT'S TASK FORCE ON AIRCRAFT CREW COMPLEMENT
SUITE 7405 • 400 7TH STREET SW • WASHINGTON DC 20590 • TELEPHONE 202-426-4869

July 2, 1981

The President
The White House
Washington, D. C. 20500

Dear Mr. President:

I am pleased to transmit to you herewith the report of the Task Force on Aircraft Crew Complement, which you appointed on March 5, 1981.

In the memorandum accompanying your letters of that date to each of the three Task Force members, you asked us to review the decision by the Federal Aviation Administration (FAA) in August 1980 to certify the McDonnell Douglas DC-9-80 aircraft for operation by a minimum crew of two persons and to make recommendations concerning the use of two-member crews in the proposed Boeing 757 and 767 and other "new generation" commercial jet aircraft. Specifically, you requested that we report to you and the Secretary of Transportation within 120 days our "recommendation whether operation of the 'new generation' of commercial jet transport aircraft by two-person crews is safe and certification of such aircraft is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety."

Our conclusions and recommendations are stated in Part I of the report, Overview and Summary of Conclusions and Recommendations. The reasons and analyses underlying our conclusions, and those of our recommendations that bear directly on the crew complement issue, are set forth in Part II, Review and Analysis of Major Issues.

In brief, we have unanimously concluded that:

-- Operation of the DC-9-80 by a crew of two is safe. Adding a third crew member would not be justified in the interest of safety.

-- FAA's certification of the DC-9-80 for operation by a minimum crew of two was proper and in compliance with the applicable provisions of the Federal Aviation Act of 1958.

-- As designed, the Boeing 757 and 767 aircraft and the A-310 aircraft being developed by the European consortium, Airbus Industrie, potentially can be operated safely by a crew of two. The addition of a third crew member would not be justified in the interest of safety.

-- The present process, improved and strengthened as recommended, will ensure proper certification of such aircraft as the Boeing 757 and 767, and proper review of the certification of such foreign-made aircraft as the A-310, from the standpoint of crew complement.

In addition to our conclusions, the report contains recommendations on ways in which we think that part of the certification process relating to crew complement can be improved and strengthened for the future. We have also included other recommendations that we thought were warranted in the light of safety-related concerns that were expressed to us and observations that we made in the course of our study.

The work of our Task Force has been made possible through the excellent cooperation we have received from many quarters. My colleagues, Lt. Gen. Howard Leaf of the Air Force, and Mr. Fred Drinkwater of NASA, and I would like to thank those senior officials of the Air Force and NASA who made available to us a wide range of talent and expertise. They have assigned to us for the duration of the study some of the leading experts in the country on the subjects relevant to the crew complement issue. For this we are deeply grateful.

In addition to relying heavily on the help of these experts, the members of the Task Force have spent a great deal of time listening to the views of interested parties from all sides of the crew complement question. We have visited the manufacturers of the DC-9-80 and "new generation" airplanes both here and abroad, and we have met with certification officials of the FAA and the British and French aviation authorities, and with the heads and chief pilots of U. S. and foreign airlines. We have also met with many individual pilots and engineers as well as with the officials of their flight crew associations and numerous others. We have ridden extensively in the cockpit on dozens of flights to obtain firsthand evidence of the atmosphere in the cockpit. Finally, we have had the benefit of extensive testimony presented during public hearings involving witnesses holding a wide spectrum of views.

We hope that the results of our work will be helpful to you in your quest to maintain and improve upon the preeminent position the United States holds in aviation safety.

Respectfully submitted,

John L. McLucas
Chairman

REPORT OF THE PRESIDENT'S
TASK FORCE ON AIRCRAFT
CREW COMPLEMENT

Dr. John L. McLucas
Chairman

Mr. Fred J. Drinkwater III

Howard W. Leaf
Lieutenant General
U.S. Air Force

July 2, 1981

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ACRONYMS

ALPA	-	Air Line Pilots Association
APA	-	Allied Pilots Association
ASRS	-	Aviation Safety Reporting System
ATARS	-	Automatic Traffic Advisory and Resolution Service
ATC	-	air traffic control
ATCRBS	-	ATC Radar Beacon System
CAB	-	Civil Aeronautics Board
CRT	-	cathode ray tube
DABS	-	Discrete Address Beacon System
DER	-	designated engineering representative
DFGS	-	digital flight guidance system
DGAC	-	Direction Generale de l'Aviation Civile
FAA	-	Federal Aviation Administration
FA Act	-	Federal Aviation Act of 1958, as amended
FARs	-	Federal Aviation Regulations
FEIA	-	Flight Engineers' International Association
G/A	-	general aviation
IFR	-	instrument flight rules
ILS	-	instrument landing system
LOFT	-	line-oriented flight training
MEL	-	minimum equipment list
MTBF	-	mean time between failures
MTBR	-	mean time between removals
NASA	-	National Aeronautics and Space Administration
NTSB	-	National Transportation Safety Board
SDR	-	service difficulty report
SPEEA	-	Seattle Professional Engineering Employees Association
TCA	-	terminal control area
TCAS	-	Threat Alert and Collision Avoidance System
USAF	-	U.S. Air Force
VFR	-	visual flight rules

PART I

OVERVIEW AND SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

President Reagan established the Task Force on Aircraft Crew Complement on March 5, 1981, to determine whether the jet transports that are being and will be introduced into commercial service over the next decade can be flown safely by a flight crew of two members. The President asked the Task Force to review the August 1980 decision of the Federal Aviation Administration (FAA) to certify the McDonnell Douglas DC-9-80 aircraft for operation by a minimum crew of two persons. The Air Line Pilots Association (ALPA) had taken vigorous exception to that decision. The President directed the Task Force to report to him and the Secretary of Transportation, within 120 days, "its recommendation whether operation of the 'new generation' of commercial jet transport aircraft," including the Boeing B-757 and B-767, "by two-person crews is safe and certification of such aircraft is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety."

BACKGROUND AND APPROACH

Certification of the DC-9-80 for operation by a crew of two and the debate it has engendered is but another chapter in a controversy that has continued in one form or another throughout most of the last half century. Although the size of flight crews is an issue that may have arisen at times as a question of economics or job security and is regarded by some as never having truly involved questions of safety, we have no doubt that it is being raised at present with genuine concerns for safety in mind.

On one side in the current controversy are ALPA, the Flight Engineers' International Association (FEIA), and some individual pilots and flight engineers. They believe that the air traffic environment, the state and reliability of aviation technology, and the demands that are placed on flight crews require that aircraft such as the DC-9-80 and those planned for service in the near future be flown by a crew of three.

On the other side of the current controversy are aircraft manufacturers, airlines, and other pilots associations and individual pilots. Considering the same basic factors, they believe that operation of the DC-9-80 by a crew of two is at least as safe as operation by a crew of three. Some on this side of the issue believe further that operation of such aircraft as the DC-9 and the B-737 is, and operation of certain future aircraft will be, safer with a crew of two than with a crew of three.

To suggest that the proponents of a crew complement of three are motivated solely by considerations of job security is, in our view, as mistaken as to suggest that the proponents of a crew complement of two are motivated solely by considerations of profit. It is not in the interests of pilots and flight engineers to have unnecessary costs imposed on the airlines for which they work, for to do so could drive the airlines to economic ruin and cause pilots and engineers to lose jobs. Similarly, it is not in the interests of manufacturers and airlines to eliminate crew members required for the safe operation of aircraft, for to do that would cause accidents, destroy public confidence, discourage air travel, harm airline revenues and manufacturers' sales of aircraft, and jeopardize the lives of airline and manufacturers' executives and their families, who also fly in the aircraft as passengers.

Although the parties on each side of the issue clearly have their own economic interests, we believe that all share the paramount objective of ensuring safety. Their differences of opinion stem not from any real disagreement on this objective, but from sincere differences on the most effective ways of achieving it. We are impressed by the commitment of the entire U.S. aviation community to the objective of ensuring safety and are convinced that the parties on all sides of the issue are willing to spare no effort in reducing the risks of aviation to an absolute minimum. The manufacturers who design and build the aircraft, the airlines who purchase and operate them, the crew members who fly them, the controllers who guide their flight, and the authorities who set the governing regulatory standards, all share in the credit for a superb safety record.

We believe that ALPA has performed a public service through its advocacy of safety measures over the years. ALPA has opened the door for others as well to raise and elaborate on numerous safety-related concerns--some that bear directly on the crew complement issue, others that bear on it indirectly, and still others that bear on it only remotely or not at all but that are nonetheless worthy of careful consideration from an overall safety standpoint.

In considering the array of concerns raised, we have come to understand more clearly that crew complement is only one among many crew-related issues that have a bearing on aviation safety. In fact, the crew complement issue seems to have become a rallying point, albeit an emotional one, for the expression of other concerns that may be even more central to the overall safety picture. We have considered these concerns and offer recommendations on those that we believe to be most important.

Addressing and making determinations on questions of aviation safety are great responsibilities, the results of which can have profound and long-term consequences for the flying public as well as the aviation industry. Although we can be proud of the nation's outstanding record of aviation safety, we are fully aware that it can be shattered by complacency. It is clear that the price for safety, like liberty. is, and always will be, eternal vigilance.

It is from this perspective that we embarked on our task. Within the 120 days we have had to complete our review and analysis, we have endeavored to consider every relevant factor, to hear every responsible proponent of every reasonable point of view, and to examine all written material presented--from handwritten letters sent by individual pilots, flight engineers, and members of the public, to voluminous filings submitted by parties with substantial interests in the outcome of our inquiry.

We assembled teams of independent experts to conduct studies of all facets of the crew complement issue. In doing so, we drew heavily from various government agencies, especially the National Aeronautics and Space Administration (NASA) and the U.S. Air Force (USAF), as well as a few independent research organizations, for the expertise of individuals who had no ax to grind on the issue before us. Each of the teams conducted an intensive review of the existing literature and analyzed all available relevant data.

We interviewed numerous pilots, airline executives, and representatives of aircraft manufacturers, the principal flight crew associations, and FAA. We also visited, and examined data provided by, representatives of European aircraft manufacturers, airlines, pilots associations, and aviation ministries.

In addition to the DC-9-80, we specifically considered the B-757, B-767, and Airbus Industrie A-310 aircraft from a crew complement standpoint. We were briefed extensively on these aircraft during visits to the manufacturers' facilities, and we reviewed substantial related documentation. As cockpit observers, we flew in the DC-9-80 and other currently operational aircraft flown by both two- and three-member crews. We also examined mockups of the cockpits of the B-757, B-767, and A-310 aircraft, and observed and participated in simulator demonstrations of the B-767 cockpit systems.

Finally, we invited public comments and held 10 days of public hearings, during which we and the principal members of the Task Force staff had the opportunity to ask questions of those presenting testimony in an effort to understand fully all the issues, data, views, and perceptions involved. The technical investigations, supplemented by the findings of our personal interviews and visits and the public hearings and comments, provided the basis for our conclusions and recommendations.

THE CONTEXT AND THE ISSUES

The operation of large commercial jet aircraft by crews of two persons did not begin with the introduction of the DC-9-80; it is not a new or radical departure from past practice in the U.S. domestic air transport industry. Jet transports operated by two-member crews have been in domestic use since the mid-1960s when the DC-9-10 and the British Aircraft Corporation BAC-111 aircraft, both certified for and operated by crews of two, were introduced into service. With the addition of new models and larger aircraft in the DC-9 series and the introduction in the late 1960s of the B-737 (certificated for a minimum crew of two and now operated by two-member crews by all but two of the carriers that operate them), jet aircraft with two-member crews have become a sizable component of the worldwide commercial fleet.

More importantly, and not to imply that there is necessarily a causal connection between these trends, as two-crew member jets have been added to the fleet in ever-increasing numbers, accident rates have declined dramatically. In 1980, two-crew member aircraft accounted for approximately 24 percent of the scheduled airline fleet and 42 percent of the scheduled airline passenger departures. There was not one fatal accident in the more than four million certified-route air carrier passenger operations in the United States that year.

The advocates of three-member crews do not dispute this impressive record, nor do most contend that aircraft operated by crews of two are unsafe. Instead, they argue that a third flight crew member provides an extra margin of safety by relieving some of the pilots' workload in unpredictable but commonly encountered situations. They argue that workload in a cockpit staffed by a crew of two often reaches a point of saturation that prevents operation of the aircraft at the highest level of safety. Automated aircraft systems are less reliable than manufacturers claim, they contend, and often increase rather than decrease crew workload. The air traffic environment, they argue, is "hostile" and is becoming less manageable as the air traffic control (ATC) system fails to keep pace with the growth in air traffic; thus, a third crew member is required to supply a third pair of eyes to observe and avoid collisions with other aircraft. In addition, the proponents of three-member crews contend that numerous demands and distractions--including excessive airline communications with the aircraft, the requirement to comply with local noise abatement and airline fuel conservation procedures, disturbances in the passenger cabin of the aircraft, and the ever-present possibility of pilot or copilot incapacitation--underscore the need for a third crew member. Nevertheless, ALPA concedes that, depending on the steps that are taken to ameliorate such adverse conditions, there may come a time when a third crew member will no longer be required.

In the case of the DC-9-80, the proponents of three-member crews argue that FAA failed in the process leading up to certification to conduct tests and follow procedures necessary to ensure that operation of the aircraft by a two-member crew would meet the highest standards of safety. In particular, they argue that FAA failed to measure crew workload properly and to include "mental" workload in its analysis; failed to use "line" pilots (in addition to test pilots) in the flight tests to determine their ability to operate the aircraft safely with a crew of two; failed to employ worst-case scenarios in the airline carrier-type ("mini-airline") flight tests that were conducted; and failed to use "full-mission" simulators to observe the performance of crews of two and crews of three for the purpose of determining which crew complement could operate the aircraft more safely.

The proponents of two-member crews--including manufacturers, airlines, and a significant number of pilots--argue that the safety record shows that operation by a crew of two is at least as safe and possibly safer than operation by a crew of three. They argue that automated aircraft systems and advances in technology in general are of proven reliability, substantially reduce crew workload, and thus eliminate the need for a third crew member. The presence of a third crew member in an environment of reduced workload can lead to boredom in the cockpit, they say, as well as pose a needless distraction to the other crew members and thus create a flight safety hazard. They argue that a properly trained and coordinated crew of two can adequately handle all flight situations that may be reasonably anticipated. They strongly dispute the claim that the air traffic environment is hostile and becoming less manageable, and contend that the benefit of a third pair of eyes in the cockpit is at best negligible. Citing the safety record and recent improvements in the ATC system, they argue that the risk of mid-air collisions is exaggerated by the proponents of three-member crews. They contend that the claims of mounting demands and distractions in the cockpit are also exaggerated and, more importantly, that the way to deal with any demands or distractions that are not related to operation of the aircraft is to insulate the cockpit crew from them rather than to add a third crew member.

The proponents of two-member crews argue that in certifying the DC-9-80 for operation by a crew of two, FAA carried out the most extensive tests to date and applied the best and most practical procedures available. They question the wisdom and value of using line pilots in flight tests during the certification process. They further argue that the aircraft development and certification schedule does not permit the use of full-mission simulators, and that, in any case, simulation is substantially inferior to actual flight tests in determining the ability of flight crews to operate aircraft safely.

Interestingly, the Allied Pilots Association (APA), which represents flight crews of American Airlines, takes a position between the opposing sides on the crew complement issue. In testimony before the Task Force, APA stated that "The essence of the two versus three-crew controversy is not whether the number 'three' is better than the number 'two,' but rather, whether two crew members can perform in their new environment as well as or better than a larger crew."

We also note that the positions of individual pilots vary depending on their particular long-term flying experiences. In our conversations with individual pilots, we found that those who are accustomed to flying in three-crew member aircraft tend to doubt that two-crew member operations are as safe. Conversely, pilots who are accustomed to flying in two-crew member aircraft tend to believe that those operations are as safe as three-crew member operations.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

On the basis of our consideration of the opposing arguments, the information and data furnished to the Task Force, and the analyses performed by our teams of experts, we have reached the following principal conclusions and recommendations. The reasons underlying our conclusions and those of our recommendations that bear directly on the crew complement issue are set forth in Part II of this report, Review and Analysis of Major Issues. Part II also sets forth subsidiary findings, conclusions, and recommendations.

Principal Conclusions

DC-9-80

- Operation of the DC-9-80 by a crew of two is safe. Adding a third crew member would not be justified in the interest of safety.

- FAA's certification of the DC-9-80 for operation by a minimum crew of two was proper and in compliance with the applicable provisions of the Federal Aviation Act of 1958.

In our opinion, it was clearly demonstrated in the certification process that the DC-9-80 can be flown safely by a crew of two in the wide variety of flight situations that may be reasonably anticipated. Although we recommend ways in which the process can be improved and strengthened for the future, we have found that the techniques employed by the manufacturer to demonstrate regulatory compliance were in accord with state-of-the-art techniques for workload assessment at the time of certification, and that the tests relating to crew complement were conducted in sufficient depth to ensure that the requirements for certification were met.

The safety record of aircraft flown by crews of two is at least as good as the safety record of aircraft flown by crews of three. In our judgment, the presence of a third crew member in the DC-9-80 would not improve the ability of the crew to operate the aircraft safely in the air traffic environment. Therefore, safety-related improvements must come from measures other than enlarging the size of the flight crew.

Although we agree that heavy demands are often made on flight crews and that crew members are often unnecessarily distracted, we believe that this problem is common to crews of three and two, and that the solution lies not in the addition of crew members but in measures to insulate flight crews of whatever size from such distractions.

Future Aircraft

- As designed, the B-757, B-767, and A-310 potentially can be operated safely by a crew of two. The addition of a third crew member would not be justified in the interest of safety.

- The present process, improved and strengthened as recommended, will ensure proper certification of such aircraft as the B-757 and B-767, and proper review of the certification of such foreign-made aircraft as the A-310, from the standpoint of crew complement.

We recognize, of course, that we cannot prejudge the outcome of the certification process as it is to be applied to future aircraft, including the B-757, B-767, and A-310. It might be determined that one type of aircraft can be operated more safely by a crew of two and another type more safely by a crew of three. However, we believe that from an aircraft systems standpoint, the level of safety achieved by the B-757, B-767, and A-310 might be even higher than that achieved in present-generation aircraft as a result of the increased redundancy, reliability, and improved information that are to be provided to the flight crews through more extensive use of digital avionics and cathode ray tube (CRT) displays.

In our view, there is nothing in the size of aircraft *per se* that requires a flight crew larger than two persons. We believe that this applies equally to large aircraft designed for long-range flights, provided that relief crews are furnished on flights of particularly long duration (e.g., longer than eight hours), and any restrictions relating to flight over water by aircraft not having a certain number of engines are met.

Recommendations Relating to Crew Complement Certification

Although we have concluded that the procedures FAA followed in certifying the DC-9-80 for operation by a minimum crew of two were proper and represented the state-of-the-art at that time, we recommend that those procedures be improved and strengthened in several respects in preparation for future certifications.

1. Rapid developments in the field of digital avionics and flight control systems, and the attendant increased complexities of computer software, require that FAA have the breadth and depth of expertise to address these areas properly during aircraft certification. FAA should make appropriate additions to its staff for these purposes. In addition, we recommend that FAA develop specific procedures for addressing the impact of such new systems on the role of flight crew members, for certifying software, and for monitoring software configuration changes.

2 At present, the only generally accepted method for evaluating workload is task/time-line analysis based on comparison with previous aircraft designs. This technique, supplemented by improved subjective evaluation methods applied by qualified pilots, will offer the best means for demonstrating compliance with FAA crew complement criteria. We recommend that FAA incorporate such methods in the tests to be employed for the certification of the B-757 and B-767 aircraft. Studies of crew performance under a variety of conditions may provide additional methods for the assessment of crew complement in the future. Line

operations (full-mission) simulation using selected line pilots could be used in conducting these studies.

3. Consultation with qualified line pilots has long proven to be beneficial and is incorporated to varying extents by manufacturers in the aircraft design process. Several aspects of new aircraft certification, such as crew procedures, workload evaluation, and training requirements, would be enhanced by augmenting FAA certification teams with qualified line pilots, perhaps working with FAA for a specified period. We recommend that FAA consider adopting such a procedure along the lines of the current procedure for using designated engineering representatives (DERs).

4. FAA should assign high priority to completing and keeping current Chapter 187 of FAA Order 8110.8 to provide formal guidelines for evaluating the effects of weather, ATC, and other system factors.

5. The minimum equipment list (MEL) identifies those items that may be inoperative when an aircraft is dispatched on a commercial flight (with appropriate operating restrictions). Recognizing that crew workload could be directly affected by the MEL, we recommend that the MEL be prepared, and related tests that examine combinations of failures be conducted, during the crew complement certification process as well as during the subsequent process relating to the development of air carriers' operating specifications.

Other Safety-Related Recommendations

Crew complement, as noted earlier, is only one among many crew-related issues that have a bearing on aviation safety. On the basis of concerns expressed by flight crews and others, as well as our own observations, we consider many of these issues to be important in the interest of promoting flight safety.

1. The aircraft separation assurance program should receive FAA's highest priority, and efforts to improve the ATC system should be adequately and promptly funded. We are encouraged by recent FAA announcements regarding plans for the rapid implementation of collision avoidance systems. As ALPA and others have urged, we recommend that FAA examine the possibility of using the ATC Radar Beacon System (ATCRBS) in the initial implementation of

these systems. Positive control of aircraft should be provided in all heavily traveled airspace and major terminal areas at the earliest possible time. Reliever airports and runways should be established in major terminal areas to provide appropriate separation between low-performance aircraft and jet transports.

2. To enhance the effectiveness of the ATC system, we recommend that FAA require all aircraft using heavily traveled airspace to be equipped with at least Mode C (altitude encoding) transponders.

3. Some form of vertical guidance, such as Visual Approach Slope Indicators, should be installed on all runways used by air carriers. Airports served by air carriers should also have instrument landing system (ILS) facilities. ILS and related ground support facilities should be upgraded to keep pace with advances in aircraft capability such as autoland.

4. Local noise abatement procedures in some cases require special flight maneuvers that could compromise safety. We recommend that FAA consider ways of standardizing procedures relating to these maneuvers with safety as the primary concern. Consideration should also be given to exempting newer, quieter aircraft from noise abatement procedures that were designed for older aircraft types.

5. Improvements should be made in the provision of pre-flight weather briefings and timely and accurate in-flight weather information, particularly in terminal areas.

6. Flight crews of whatever size should be relieved of and insulated from demands and distractions that do not relate to flying the aircraft. Some measures, such as prohibiting non-flight-related cockpit conversations and communications during critical phases of flight, have been proposed. Potential distractions can be further reduced through the increased use of single transponder code assignments and automated communications devices, and through the establishment of direct communications links between the ground and passenger-cabin crews to deal with such matters as the personal needs of passengers. We also recommend further reduction of non-essential contacts between the passenger cabin and the cockpit.

Cabin crews should be trained to deal with passenger problems and to operate cabin equipment without the assistance of flight crew members.

7. Although the incapacitation of a flight crew member is a rare occurrence, the airlines should uniformly establish programs to train crew members to recognize subtle incapacitation of a fellow crew member and to follow appropriate procedures in the event of such an emergency. We also recommend the further development and use of restraining devices that would prevent an incapacitated crew member from interfering with the flight controls during critical phases of flight.

8. We are impressed with efforts by air carriers to reduce the number of crew-related accidents by improving training in command, leadership, and cockpit resource management skills, and by establishing line-oriented flight training (LOFT) programs. In addition, we recommend that airline pilots serving as second in command also be required to have an FAA airline transport pilot certificate with type ratings for the aircraft on which they serve.

9. Special attention should be directed to concerns expressed by some pilots over what they consider to be an excessively punitive approach by FAA in enforcing safety regulations. We recommend that ways be sought to instill and strengthen a sense of trust and cooperation between FAA and members of flight crews. In particular, we recommend that NASA's Aviation Safety Reporting System (ASRS) be strongly supported by FAA and NASA, and that serious consideration be given to strengthening the immunity provisions applicable to ASRS and to protecting aircrews from unwarranted disclosure of conversations recorded on cockpit voice recorders.

10. Many of the Federal Aviation Regulations (FARs) relating to flight crew responsibilities appear to be unnecessarily complex. An effort should be made to simplify and clarify the FARs to make them more understandable and easier to use.

11. Enroute, terminal area, and approach charts are frequently designed in a way that makes them difficult to use. The design and content of these charts should be improved.

12. The Secretary of Transportation should take steps to expedite the implementation of FAA's program (the Aviation Safety Analysis System Project) to strengthen its ability to collect, process, and disseminate safety-related information necessary for decision-making in FAA and the aviation industry generally. The Aviation Safety Analysis System is being designed to be compatible with other accident data systems, including those maintained by the National Transportation Safety Board (NTSB) and the International Civil Aviation Organization. It is essential that this system include worldwide data.

13. The research conducted by FAA, NASA, and the Department of Defense on the impact of automation on the role of flight crews should be continued and expanded. We also recommend that strong support be given to the development and evaluation of safety-related systems, such as Cockpit Display of Traffic Information and Heads-up Displays, as well as to ongoing research on the effects of fatigue, desynchronosis, and length of duty period on flight crew performance.

Finally, we urge that FAA take special care to guard against any diminution of existing high safety standards among air carriers as a result of economic changes within the industry. New entrants must be held to the same high standards that long-established carriers have maintained, and established carriers must be encouraged to maintain their high standards regardless of pressure to cut costs in the face of new competition. The experience to date has been excellent, and we are confident that FAA can be counted on to carry out its duty under the law "to maintain the highest standard of safe, reliable air transportation in the United States."

PART II

REVIEW AND ANALYSIS OF MAJOR ISSUES

Throughout our deliberations on the issue of crew complement, we focused on safety as the central concern and ultimate goal of all interested parties. Recognizing the overriding importance of this concern, we structured our investigations and analyses in terms of the safety-related issues that have been raised by the flight crew associations, manufacturers, airlines, and government agencies involved in the crew complement controversy.

The ultimate measure of aviation safety is the historical record of accidents and other mishaps (e.g., near mid-air collisions, FAR violations). Accordingly, our review and analysis of the issues surrounding the crew complement question begins with a review of the major studies conducted by the various interested parties, as well as the results of our own independent analyses of accident and incident rates and trends to identify crew-related factors.

However, because the aviation system, like any other complex system, is constantly changing and evolving, it is not possible to rely solely on retrospective studies to reach a defensible conclusion with regard to crew complement in future aircraft. In addition to changes in the volume of air traffic, qualitative changes in the types of aircraft and operations conducted are likely to occur. To handle these changes, the ATC system is continually incorporating new operating rules and new technology. Significant questions have arisen regarding the adequacy of these changes to meet the demands of the larger volume of air traffic, particularly in the "hostile" environment in which some believe aircraft recently or soon-to-be certified will be flying during their useful lifetimes. Our review of the ATC system and its implications for crew complement is presented in the second section of this part.

To improve operating efficiency and enhance safety, manufacturers are incorporating technological changes into the cockpits of new generation aircraft. Again, these changes must be fully understood before any determination regarding crew complement can be made. Are the role and functions of the flight crew different in new technology aircraft? If so, what are the implications for the size of the crew? The role of the flight crew in operating and monitoring the new systems, and the reliability of those systems, are key considerations that have been raised in the crew complement controversy; these issues are discussed in the section on cockpit systems and technology.

The fundamental question underlying the crew complement issue relates to the rationale and method by which tasks and duties are allocated between technological systems and their human operators. One major human factors issue is the question of how pilot workload is measured: do the manufacturers and FAA use techniques that accurately reflect pilot workload in light of changes in the ATC system and the new cockpit technology? A related question concerns the role of simulation in certification. Other human factors issues deal with crew communication, integration, and coordination, the possibility of incapacitation, and the practice of "see and avoid." These issues are discussed in the section on human factors.

Under the Federal Aviation Act of 1958, as amended (FA Act), any new airplane design must be issued a type certificate by FAA before it can be introduced into service. Part 25 of the FARs sets forth airworthiness standards for the issuance of these certificates for transport aircraft. Under Section 25.1523, the applicant (manufacturer) is required to establish that its proposed crew complement is sufficient for safe operation, considering the workload of individual crew members. Appendix D to Part 25 presents the factors to be considered in analyzing and demonstrating workload for minimum flight crew determination. The final section of this part of our report reviews the adequacy of the certification process and its application to the DC-9-80 and future aircraft.

SAFETY RECORD

The question of whether aircraft should be flown by two or three crew members would be straightforward, and the answer clearcut, if accident and other mishap data clearly supported one side or the other of the issue. Numerous studies have been conducted or cited by the parties in the crew complement controversy in an attempt to demonstrate that aircraft flown by either two or three crew members are safer.

In an effort to evaluate the claims and conclusions of the various parties, the Task Force reviewed the major studies conducted and cited by government agencies, manufacturers, airlines, and flight crew associations in presenting their viewpoints on the crew complement issue. In the course of our review, we evaluated the validity of the data base used in each study, examined the techniques employed to normalize the data (i.e., to eliminate accidents caused by factors unrelated to crew performance), and attempted to identify any biases inherent in the analytical approaches used or the conclusions reached. We then compiled a complete data base that had not been normalized or modified, and performed our own independent analysis. We encountered difficulty in compiling a comprehensive data base, however, because the various data bases that contain information related to the safety of air carrier operations are dispersed, inconsistent, incomplete, and often only partially accessible. Furthermore, no single federal agency is responsible for the reporting, collection, processing, quality control, and analysis of such data. In this regard, we recommend that the Secretary of Transportation support FAA in its efforts to assume this responsibility by implementing the Aviation Safety Analysis System currently being developed.

The principal material examined by the Task Force included the following:

- Summary Report of 1977-1978 Task Force on Crew Workload, FAA Task Force (FAA-EM-78-15), December 1978, and update (FAA-RD-81-34), April 1981--concludes that "two-member crew airliners are being operated in as safe a manner as three-member crew airliners," based on an analysis of the accident rates of the DC-9 vs. the B-727 and two- vs. three-crew member aircraft.

- Crew Complement Evaluation Study, United Air Lines and ALPA, March 1969--relying on observations made by B-737 pilots, claims that the third crew member was able to identify significantly more traffic and missed flight procedures than either of the two pilots.

- The Jet Transport Safety Record, Boeing Company, April 1981--reviews aircraft accidents, violations, near mid-air collisions, incapacitations, and mid-air collisions, and concludes that two-crew member jet transports have a better safety record than three-crew member transports. (Preliminary results were presented to interested parties in March 1980.)

- Refutation of the Boeing Crew Complement Presentation, R.K. Hinz, Jr., Western Airlines, July 1980--claims that Boeing's normalization process in determining crew-related accidents did not follow the NTSB "probable cause/factor" and therefore skewed the results to favor the two-member crew. Using NTSB cause factors, the author claims that three-member crews and the B-727 enjoy lower accident rates than do two-member crews and the DC-9.

- ALPA Analysis of ASRS data compiled by NASA, covering the period May 1978-June 1980--notes a significantly greater reporting rate of altitude deviations and clearance errors involving two-member crews.

- The Issue is Air Safety, FEIA, March 1981--a compendium of thoughts, studies, and points on issues extracted from various papers published by other authors, claims that DC-9 ATC violation rates are significantly higher than B-727 rates, and that third-generation aircraft are experiencing higher disability rates than second-generation aircraft. (Does not, however, compare rates for two and three member crews.)

- Analysis of the Crew Complement Issue Concerning Air Carrier Two-Engine Turbojet Aircraft, C.M. Schonberger, September 1980--dismisses the use of accident statistics as inconclusive with regard to the question of crew complement, and focuses on other types of statistics (e.g., violations, near mid-air collisions). Used by FEIA to support its position that three-crew member aircraft are safer.

- No Compromise with Safety, The Crew Complement Question, Europilote and U.S. ALPA, summer 1980--supports the need for three-member crews based on workload considerations, but notes that "although ...figures indicate an advantage of the three-man crew, *caution is again advised* when attempting to use accident statistics in comparing various types of aircraft." Strongly supports the United study and criticizes the Boeing study.

- Testimony presented during the Task Force hearings and supporting documentation, including materials submitted in rebuttal.

Following a detailed review of these studies, we compiled and analyzed data related to:

- Accidents;
- FAR violations;
- Air traffic system errors;
- ASRS incidents;
- Near mid-air collisions; and
- Mid-air collisions.

The results of our review and analysis are summarized in the following sections. (An expanded discussion of the studies we reviewed and the results of our independent analysis is available in the permanent records of the Task Force.)

ACCIDENTS 1/

The development of valid conclusions from statistical data is a difficult task, especially when addressing a subject as complex as aviation safety. If an analysis of accident data is to serve as a sound basis for reaching conclusions with regard to crew complement, certain steps must be followed:

1. Define the scope of the study (e.g., accident types, geographical boundaries, time periods).

2. Establish a basis for comparison (e.g., accident rate per departure or per hour).

1/ NTSB defines an accident as "an occurrence incident to flight in which, as a result of the operation of the aircraft, any person (occupant or non-occupant) receives fatal or serious injury or any aircraft receives substantial damage."

3. Compile a reliable data base consistent with the selected scope of the analysis.

4. Compare the relevant accident rates of selected aircraft or groupings of aircraft.

5. Determine the statistical significance of the observed accident rate differences. 2/

6. Consider the relevance of the findings to crew complement, including an examination of accident files as required.

With the possible exception of step 5, determining statistical significance, all these steps involve substantial judgment. It is therefore not surprising that no two of the studies reviewed by the Task Force, or our independent analysis, reach the same specific findings. Importantly, however, several of the studies we reviewed made no attempt to perform the last two--in our view, critical--steps, and attempted to support their point of view simply on the basis of apparent accident rate differences.

Most of the recent literature dealing with the implications of accident data for crew complement referred to two studies performed by FAA and Boeing.

The FAA study was published in 1978 and updated in 1981. The 1978 report covered a 10-year period (1967-1976) and treated five aircraft types (B-727, DC-8, B-737, DC-9, and BAC-111). In the 1981 update, the time period was extended through 1979. In both cases, accident and exposure 3/ data were limited to U.S. certificated air carriers.

The most relevant finding of the FAA study was a statistically significant lower accident rate (per million departures) for two-crew member aircraft than for three-crew member aircraft. Despite this

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2/ Statistical significance is a measure of the confidence that an observed difference is real and not due to measurement error. In our analysis, we used the chi square technique (95 percent confidence level) to determine statistical significance.

3/ "Exposure" is a measure of the number of chances an aircraft has to be involved in a mishap, usually expressed as number of flight hours or number of departures in a specified time period.

finding, however, FAA reported in 1978 that "The only reasonable conclusion...is that at present, two-member crew airliners are being operated in as safe a manner as three-member crew airliners." The 1981 update similarly reported that "...these data lend no support to the proposition that use of two crew members in an appropriately designed aircraft derogates safety."

Proponents of three-member crews have criticized the normalization technique employed by FAA to "delete categories of accidents which could not represent in-flight aircrew involvement." The Task Force also found several inconsistencies in FAA's implementation of its own normalization process. Accordingly, we performed a normalization of FAA data by applying FAA's normalization criteria and the accident causal factors listed in its report.

Our normalization excluded 50 accidents that had been retained by FAA. As a result, our normalized two-crew member rate was slightly higher than the normalized three-crew member rate, but the difference was not statistically significant. Thus, the Task Force agrees with the basic conclusions presented in the FAA study.

Boeing, on the other hand, claims that two-crew member aircraft have a superior safety record. Boeing's study, **The Jet Transport Safety Record**, covers the time period 1959-1980, and includes worldwide as well as U.S. air carrier data. Three sets of accident data were examined: all accidents, hull-loss accidents, and fatal accidents.

Boeing claimed a statistically significant superiority in the safety record of two-crew member aircraft (based on accidents per million departures) for worldwide air carriers in all three categories of accidents for the 1968-1980 period. A similar conclusion was reached when only "crew-caused" accidents were considered.

Based on an in-depth review, the Task Force finds the accuracy, completeness, and objectivity of Boeing's data base to be without serious question; however, we are not convinced that these data demonstrate the superiority of either a two- or three-member crew.

Even among those accidents involving a crew factor, it is imperative to question whether or not the *size* of the crew was a factor. In most cases, a causal relationship was not evident; for example, in many cases, time was not available for another crew member besides the person at the controls to take any action, or the pilot in command already had all reasonable information inputs. In sum, it is the opinon of the Task Force that inappropriate inferences can be and have been drawn from the Boeing document.

In the "Review of Additional Data" submitted to the Task Force, ALPA criticized the Boeing analysis on the basis that the three-crew member aircraft group included wide-body aircraft that have higher accident rates. ALPA argued that since the three-crew member grouping was not homogeneous, a comparison of all three-crew member aircraft with all two-crew member aircraft was improper. Although this objection may have some validity, ALPA proceeded to include the CV580/600/640, F27/FH227, and YS11 turboprop aircraft in the two-crew member grouping to demonstrate a superior safety record for short/medium-haul three-crew member aircraft.

The Task Force does not agree with the rationale for ALPA's analysis, since ALPA's supporting data show a statistically significant higher crew-related accident rate for the turboprop aircraft compared to the two-crew member turbojet, thereby creating a non-homogeneous grouping of questionable relevance.

In addition to reviewing these and other studies, the Task Force performed an independent analysis of accidents, starting with a data base that had not been normalized or modified by others.

We limited our study to scheduled U.S. air carrier passenger turbojet/turbofan aircraft. The time period 1971-1980 was selected to encompass a relatively broad base of experience during which significant numbers of two-crew member aircraft were in operation, and an operating environment that was reasonably representative of current conditions. Exposure data consistent with the scope of our study were obtained from the Civil Aeronautics Board (CAB) and, to fill information gaps, from six carriers. All accident data were obtained from NTSB.

For 230 accidents, we created an automated data base containing 14 variables per accident as well as exposure data by aircraft type and air carrier. Evaluation of accident rates by type of aircraft, number of engines, air carrier, pilot experience, and average flight duration revealed that none of these variables disproportionately influenced the total, destroyed, or fatal accident rates.

Of the 230 accidents, only 74 were considered to be "crew-related" (i.e., pilot or flight engineer identified as a "probable cause" or "factor" by NTSB investigators). Crew-related factors were involved most often in takeoff and landing accidents. Both the total and crew-related accident rates have decreased dramatically over the past 10 years, while the destroyed aircraft and fatal accident rates have remained relatively constant, between zero and one per million departures.

We evaluated accident rates by crew size by comparing the two- and three-crew member B-737 operations as well as all two- and all three-crew member aircraft operations (see Table 1). Although the majority of these comparisons indicated a lower accident rate for two-crew member aircraft, only one comparison yielded a statistically significant difference: the 10-year cumulative total accident rate per departure for three-crew member aircraft appeared to be significantly higher than the rate for two-crew member aircraft. The B-747 data (which was dominated by turbulence injuries) accounted for most of this difference. If the accident rate is based on accidents per flight hour (instead of accidents per departure), the difference in total accident rates is no longer significant. (Since most accidents occur in terminal areas, the accident rate based on departures is generally considered to be more meaningful than the rate based on flight hours.)

TABLE 1

SUMMARY OF U.S. PASSENGER TURBOJET AIR CARRIER ACCIDENTS (1971-1980)

	Two-Member a/ Crews	Three-Member b/ Crews
Total Accident Rate Per Million Departures	2.86	6.28 d/
Crew-Related Accident c/ Rate Per Million Departure	1.46	1.73
Total Accident Rate Per Million Hours	3.09	3.47
Crew-Related Accident c/ Rate Per Million Hours	1.58	0.96

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a/ B-737, DC-9, and BAC-111.
b/ DC-8, DC-10, L-1011, B-720, B-707, B-727, B-737, and B-747.
c/ Using NTSB cause/factor as crew-related.
d/ Includes B-747 turbulence injuries.

In an effort to refine our understanding of the causes of the 74 crew-related accidents, we reviewed the hard-copy NTSB accident reports and dockets. This effort was not productive, however, because NTSB reports describe in detail only what occurred, not why it occurred. Specifically, none of the NTSB investigations addressed crew size as a causal factor, even indirectly.

Based on our independent study of the accident record, we conclude that the available accident and exposure data do not demonstrate a safety advantage for either two- or three-crew member aircraft.

FAR VIOLATIONS

The Task Force performed an analysis of air carrier violations similar to those performed by Mr. Schonberger, Boeing, FEIA, and ALPA, beginning with raw data and normalizing to crew-related violations.

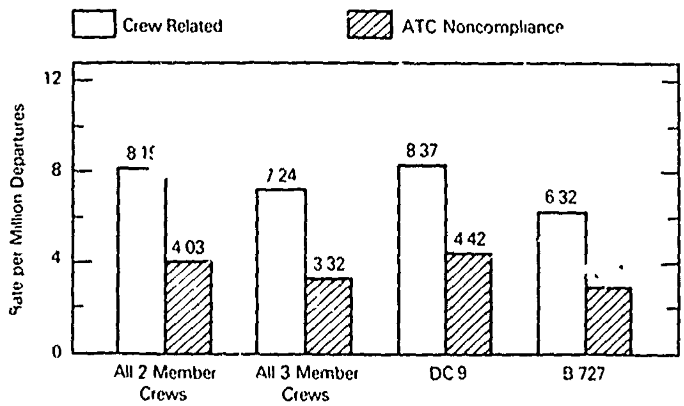
The violations data were taken from the Air Carrier Enforcement History, 1975-1979, published by the FAA Flight Standards National Field Office, which contains legal enforcement reports of violations upon which final action was taken. During this period, 258 violations were documented.

Using FAA violations categories, we were able to identify 189 of the 258 violations as being crew-related. Of these, 13 were not identified in the reports by aircraft type, 67 occurred on two-crew member flights (53 DC-9), and 109 occurred on three-crew member flights (63 B-727). We related these data to exposure to calculate violation rates for two-member crews, three-member crews, the DC-9, and the B-727, recognizing that the validity of these rates is compromised by the lack of aircraft type information in some cases and the fact that some violations occurred during training, cargo, or ferry flights (for which we had no exposure data). The sample size was too small to compare the rates for other aircraft (e.g., 5 two-crew member B-737 violations and 3 three-crew member B-737 violations). The violation rates are shown in Figure 1.

Figure 1

Air Carrier Turbojet Violations

(1975-1979)



We were also able to identify violations involving non-compliance with ATC instructions. Of 92 such violations, nine occurred on unknown aircraft types, 33 had two-member crews (28 DC-9), and 50 had three-member crews (30 B-727). Relating these data to exposure indicated that the two-member crews had a slightly higher violation rate than the three-member crews, and the DC-9 had a higher rate than the B-727, but neither comparison showed statistically significant differences.

The number of DC-9 violations shown in the Schonberger study was similar to the number we calculated for the period 1975-1979. However, Schonberger evidently relies on FAA violation reports rather than violations on which enforcement action was taken. Furthermore, he did not calculate violation rates.

The .Boeing study showed little significant difference between violation rates for two- and three-member crews, while FEIA showed the DC-9 rate to be about twice that of the B-727 rate (using a data base covering 1968-1978). ALPA also found the DC-9 rate to be higher than the B-727 rate.

In view of the differences in the analytical approaches employed and the results of the studies we reviewed, as well as the results of our independent analysis, we conclude that the data do not indicate a significant difference between the violation rates for two- and three-member crews.

ASRS INCIDENTS

The ASRS is a voluntary reporting system used principally by pilots and controllers to identify hazards to which their own actions may have contributed. The Task Force examined the ASRS data that had been referred to by various parties in the crew complement issue, keeping in mind the limitations of such data. The principal document we reviewed was a July 1980 set of incident reports covering the period from May 1978 through mid-June 1980, which had been requested by FAA in the course of its examination of the crew complement issue.

ALPA's analysis of the data set led to the conclusion that two-member crews had a significantly higher rate (per million departures) of reported deviations from cleared altitude and other clearance problems than did three-member crews. In addition, ALPA submitted studies to the Task Force citing ASRS report sets indicating that two-member crews were more affected by distractions during the performance of their duties.

To evaluate these findings, the Task Force conducted independent analyses of altitude deviations and distraction incidents. In our assessment of altitude deviations, we identified 282 occurrences. Since the ASRS reports contain no codes indicating crew size, we reviewed the narratives of all two-engine reports for any indication of crew size. We focused particularly on statements of crew activities, route being flown, and geographical location. Using this procedure, we were able to identify the crew size on 86 of the 149 two-engine aircraft reports.

Departure data indicate that approximately 10 percent of all two-engine turbojet departures were three-crew member B-737s during this time period. If the 63 reports in the "unknown" crew-size category are proportioned accordingly, the standard chi-square test suggests a high probability that two-member crews had a significantly higher reporting rate of altitude deviations than three-member crews. We obtained similar results from our independent review of the ASRS distraction study cited by ALPA in its testimony.

We also conducted an independent study of the May 1978-June 1980 ASRS data set of reports of near mid-air collisions. Our objective was to examine the role of the third crew member in those incidents known to have been reported by three-member crews and in which the conflict was noticed in time for evasive action. In these instances, the third crew member was the first to see the conflicting traffic in 37 percent of all cases.

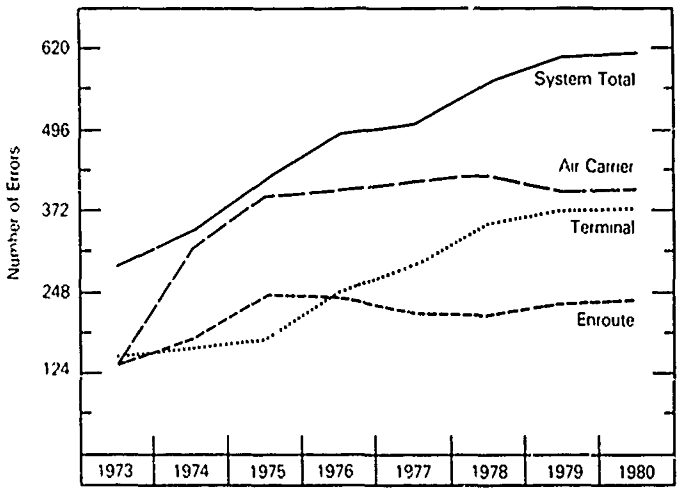
The ASRS data base is useful in identifying significant problems--and potential solutions--in the aviation system. However, because crew complement is not directly encoded, it must be inferred from other factors. Furthermore, ASRS is a voluntary system and the reports submitted are not verified. For these reasons, ASRS data cannot be used to support definitive conclusions with regard to the crew complement issue. We do recommend, however, that the implications of the ASRS findings for cockpit system design, certification, and flight crew operating procedures be seriously considered.

AIR TRAFFIC SYSTEM ERRORS

Information on air traffic system errors 4/ was extracted from the FAA AAT-20 System Error Reporting System and the FAA Monthly Management Report, January 1981. Data on system errors by aircraft type were available for the period 1973-1980. Data on instrument operations at FAA airport traffic control towers were available for 1971-1980. We were unable to compare system errors by aircraft type to exposure time, however, because the system error data did not segregate U.S. from non-U.S. aircraft and we had exposure time for U.S. carriers only.

The number of reported system errors related to air carrier jet aircraft has remained relatively constant since 1975, although the total number of errors has increased over the past eight years. In addition, the number of enroute errors has remained relatively constant since 1975 while the number of terminal area errors has increased, apparently reflecting an increase in general aviation (G/A) operations (see Figure 2).

Figure 2
ATC System Errors
(Jan. 1973 - Dec. 1980)



4/ FAA defines a system error as any operational error that results in less than the minimum specified separation between two or more aircraft and terrain or obstacles. Thus, system errors are recorded for situations ranging from slight position deviations of no real-time consequence, to encounters where evasive action has been necessary to avoid a mid-air collision. With the exception of separation services being provided to VFR traffic within a terminal area, system errors are reportable only for IFR traffic.

NEAR MID-AIR COLLISIONS

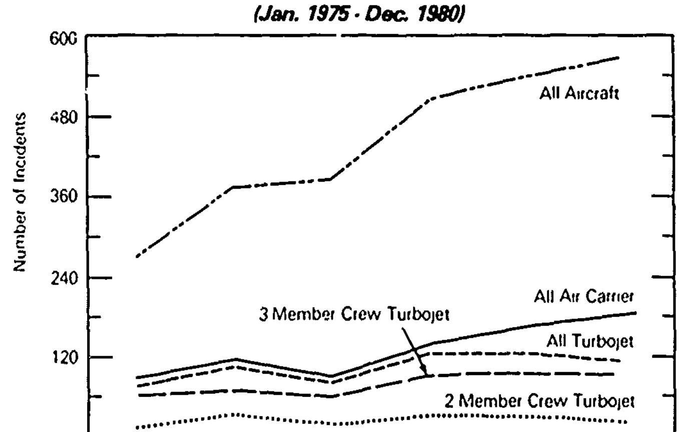
The Task Force used the FAA computer data base covering the period 1975-1980 to analyze near mid-air collision rates. By removing non-U.S. carrier incidents, we were able to relate U.S. air carrier incidents to U.S. carrier exposure within the United States.

While the number of reported incidents for all U.S. aviation has increased substantially since 1975 (again probably reflecting an increase in G/A), the number of incidents for all U.S. carrier turbojets has remained relatively constant and has in fact decreased since 1979 (see Figure 3).

Figure 3

Near Mid-Air Collisions

(Jan. 1975 - Dec. 1980)



269	372	384	504	539	566
82	117	87	138	145	158
77	104	80	124	125	111
62	70	61	92	96	89
15	34	19	32	29	22
1975	1976	1977	1978	1979	1980

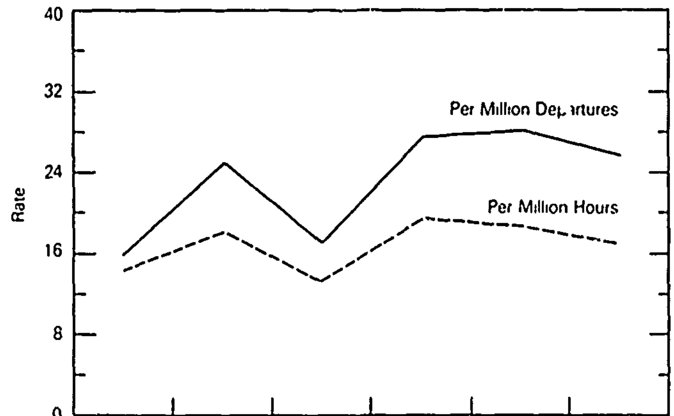
Similarly, the rate for near mid-air collisions per departure has declined since 1979 and the rate per hour has declined since 1978 (see Figure 4).

Figure 4

Near Mid-Air Collisions

Air Carrier Turbojet

(Jan. 1975 - Dec. 1980)



15 96	25 04	17 17	27 48	28 32	25 82
14 26	18 21	13 22	19 47	18 70	17 00
1975	1976	1977	1978	1979	1980

Of the total number of incidents reported, 151 involved two-member crews and 469 involved three-member crews. Near mid-air incident rates are slightly higher for two-crew member aircraft (16.02) than for three-crew member aircraft (15.19) when measured on an hourly basis. However, the rate per million departures is significantly higher for three-crew member aircraft (25.17) than for two-crew member aircraft (15.09). These rates per million departures are similar to the results of the Boeing study, which used a 1973-1979 data base.

The Schonberger report states that DC-9 crews were involved in 60 percent of the two-crew member near mid-air incidents. Our analysis supports this statement. However, Schonberger does not relate this percentage to exposure. Our analysis indicates that the DC-9 has a lower rate per hour or per departure than most other aircraft types.

It is important to note that the submission of near mid-air collision reports is voluntary and subject to individual pilot determinations of severity. The only significant difference our analysis shows between two- and three-member crews is that the latter have a rate of recorded near mid-air collisions per million departures about twice that of the former.

MID-AIR COLLISIONS

The Task Force examined the NTSB accident records of mid-air collisions involving U.S.-certified air carrier turbojet/turbofan aircraft in the 1967-1979 time period (selected to coincide with the time period used by the FAA Task Force on Crew Workload).

Twelve pertinent mid-air collisions occurred in this 13-year period (only one in the last eight years, the much-publicized collision in San Diego in 1978 between a B-727 and a Cessna 172). The 12 collisions involved three types of turbojet/turbofan aircraft: DC-9 (six collisions), B-707 (three collisions), and B-727 (three collisions). Since all collisions occurred in or near a terminal area, we computed the respective mid-air rates using the number of departures as the exposure factor. Departure data for the DC-9 and B-727 were taken directly from the FAA Task Force reports, and the corresponding B-707 departure data were obtained from CAB.

Some accidents were judged by NTSB to be unavoidable by the crew. Accordingly, to provide a more meaningful comparison, we normalized the data by considering only those accidents in which the crew could conceivably have seen the other aircraft in time to avoid the collision (see Table 2).

TABLE 2

MID-AIR COLLISIONS
U.S. AIR CARRIER TURBOJET/TURBOFAN AIRCRAFT
(1967-1979)

Crew Size	Total Pertinent Collisions	Total Pertinent Rate Per Million Departures	Normalized Collisions	Normalized Rate Per Million Departures
DC-9	6	0.441	4	0.294
B-727	3	0.156	2	0.104
B-707	3	0.602	3	0.602

Although the raw data suggest differences in the mid-air accident rates among the three types of aircraft, the number of accidents is too small to infer any statistical significance.

As a further complication, one of the DC-9 accidents occurred with a fully qualified captain in the cockpit jumpseat, in addition to the two regular crew members. This accident cannot reasonably be attributed to either two- or three-crew member operation. If this accident is excluded, a direct comparison can be made between the two- and three-crew member aircraft (see Table 3).

TABLE 3

MID-AIR COLLISIONS
COMPARISON BY CREW SIZE

Crew Size	Total Pertinent Collisions	Total Pertinent Rate Per Million Departures	Normalized Collisions	Normalized Rate Per Million Departures
two	5	0.367	3	0.220
three	6	0.238	5	0.207

Based on our review of the safety record, we find that:

- Considering all indicators (e.g., accidents, violations, near mid-air collisions), the data are contradictory in some cases and inconclusive in others.
- Considering only accidents, two-crew member aircraft have experienced a lower (but not statistically significant) rate per million departures than three-crew member aircraft.

Overall, two- and three-crew member aircraft have statistically indistinguishable safety records. It is important to note that this finding is based on more than 14 years of experience during which two-crew member aircraft made more than 19 million departures and accumulated over 17 million hours of flight time. In our judgment, therefore, aircraft flown by crews of two are at least as safe as aircraft flown by crews of three.

AIR TRAFFIC ENVIRONMENT

For an airplane to operate safely, no matter what size the crew, it must fly in a safe environment. According to ALPA and FEIA, the present air traffic environment is "hostile" and "dangerous." On the basis of our analysis, we do not agree with this characterization. We do recognize, however, that certain features of the ATC system can add to, as well as ease, the burden of the aircrew, and therefore warrant consideration.

At issue is whether aircraft with two pilots can rely on the current and future ATC system to provide safe separation from terrain and other aircraft, or whether the traffic will be so heavy and technology either so inadequate or complex that three crew members are needed. 5/

TRAFFIC VOLUME, GROWTH, AND MIX

In 1980, there were approximately 234,000 aircraft in the U.S. inventory. These included:

- 3,700 air carrier aircraft (including helicopters);
- 20,000 military aircraft (including helicopters); and
- 210,000 G/A aircraft.

Air carriers as a group fly the smallest number of aircraft and account for only 15 percent of operations (landings or takeoffs) at airports with FAA towers. Air taxis account for an additional 7 percent of operations. However, together these two groups accounted for 200 of the 220 billion passenger miles flown in the United States in 1980.

5/ The proponents of three-crew member aircraft have expressed their concern to us about crew complement on the DC-9-80, B-757, B-767, and A-310, but not on existing or other new aircraft (e.g., DHC-7, SD-330) that will operate in the same air traffic environment.

A substantial amount of military flying takes place in the United States. These aircraft fly on training routes below 10,000 feet as well as in specially designated military areas at intermediate and high altitudes. Although many military enroute operations cross airways used by air carriers and G/A aircraft, they have minimal interaction with air transport operations.

The major users of airports are G/A aircraft, which account for as much as 74 percent of all operations at FAA towers. Most G/A aircraft operate in accordance with visual flight rules (VFR), but 70 percent are equipped with transponders, and as many as 30 percent have Mode C transponders with altitude encoding equipment that permits them to operate above 12,500 feet. Nevertheless, less than 7 percent of the G/A aircraft permitted to fly in that airspace actually do so. A more serious concern about the mix of aircraft traffic is in the lower altitudes near terminal areas where traffic density is higher.

FAA expects U.S. air traffic to increase significantly over the next decade. Between 1980 and 1992, total operations at airports with FAA traffic control service are expected to increase 43 percent. The mix of aircraft is forecast to change substantially as well. According to FAA, the number of air carrier operations will increase 21 percent over this time period, while G/A aircraft operations will increase 49 percent. At ATC centers, which control enroute air traffic, it is estimated that almost as many G/A operations as air carrier operations will be handled by 1992. Today, only 30 percent of the workload at centers is attributed to G/A aircraft.

FAA projections of aircraft traffic growth are contested by the manufacturers. According to Boeing, the increase in jet transport and G/A operations has been overstated. Moreover, Boeing believes that factors that have prevented rapid growth in mixed operations over the past few years--particularly the high cost of fuel--suggest a leveling and perhaps even a reduction of future air traffic. FAA defends its forecast by noting that growth has occurred in air taxi, commuter, and corporate operations despite rising fuel costs.

The Task Force does not consider these differences in growth projections to be significant; in all cases the trend is upward. The more meaningful questions to resolve deal with the impact this growth will have on the ATC environment and whether it has implications for crew complement.

ALPA and FEIA are concerned about the adequacy of the ATC system to handle the projected increase in traffic in the coming decades. ALPA, in a report to the Task Force, stated that aircraft flown with a "three-member crew will make a significant contribution to reducing the hazards of operating in that environment." ALPA regards the principal duties of the third crew member as reducing the workload of the other two crew members so that they can maintain traffic vigilance, and assisting in the traffic watch during the critical departure and landing phases of flight.

Aircraft manufacturers and certain airlines argue that technology is already easing the pilots' workload, particularly in terminal areas, and that the traffic watch potential from the third crew member's seat is inconsequential because of poor visibility. Moreover, they contend that the air traffic environment will be improved in the future as a result of changes planned for the ATC system.

The Task Force considers the air traffic environment to be a complex and demanding place in which to operate. However, it is evident that the ATC system has accommodated the growth satisfactorily. As traffic has increased over the years, the safety record has steadily improved.

Through testimony given at the hearings and our independent examination of the current and future ATC systems, however, we became aware of the need for an aggressive program of continual improvements in ATC systems and procedures, as well as in airport facilities. Although not always directly related to the crew complement question, such improvements clearly deserve attention in the interest of maintaining safety in aviation.

ATC SYSTEM TECHNOLOGY

The current ATC system features an automated radar terminal system (ARTS) and enroute computer system (NAS stage A) enhanced by airborne beacon transponders with altitude encoding equipment. It incorporates a highly redundant network of communications. The enroute system, which covers every region in the United States, is organized around 25 centers. These facilities provide separation service for all aircraft operating under instrument flight rules (IFR) in airspace governed by the United States.

ATC responsibility is transferred from a center to a terminal approach control facility, or tower, when aircraft fly in the general altitude below 7,000 feet and within approximately 35 miles of a terminal. Arrival and departure traffic is sequenced and separated through towers using visual and radar separation procedures. There are currently 23 terminal control areas (TCAs) encompassing 26 airports where all traffic is under positive ATC control. Some TCAs, such as New York, cover more than one airport. Only specially equipped aircraft are permitted to land and take off at airports covered by TCAs.

Many qualified G/A pilots find operations at TCAs so demanding that they prefer not to operate within them. Air carrier pilots, in contrast, prefer operating in TCAs because they offer much greater protection from VFR traffic. However, operating in TCAs does not eliminate the need for crew vigilance due to possible conflicts attributable to either pilot or controller error, or inadvertent intrusions by VFR aircraft. The Task Force believes that segregation of types of aircraft through more positive-controlled terminals and reliever airports is an important measure for alleviating current and anticipated problems in high-density areas.

In addition, many airports outside of TCAs are served by air carriers. Many of these lack basic safety facilities such as FAA towers, instrument landing systems, approach lights, and radar services. However, these deficiencies do not relate directly to the crew size controversy. An aircraft flown with any size crew could operate more effectively if such deficiencies were corrected.

Other factors affecting the air traffic environment at most airports in the United States are procedures to deal with noise abatement and fuel conservation. ALPA argues that the additional work required to comply with these procedures can reduce the slim margin of error they claim now exists. The Task Force agrees that these procedures can increase cockpit workload, but we do not agree that they result in a significant reduction of safety. We recommend that these procedures be standardized with safety as the primary concern. In addition, consideration should be given to exempting the quieter and more fuel-efficient aircraft types now entering service from these requirements.

The reliability of radar and other basic ATC technology also affects the safety of the air environment. ALPA contends that the frequency of system errors is another indication of the hostile air environment. Although system errors do indeed take place, our data do not support ALPA's contention. As shown in the Task Force's analyses of the safety record, the number of system errors relating to air carrier aircraft has remained relatively constant since 1975 even though traffic has increased.

ALPA has also claimed that ATC computer systems are unreliable. Using FAA data, the Task Force studied the incidence of failures in 1977 and 1980 for four systems: automated radar terminal system, enroute radar data processors, airport surveillance radars, and enroute surveillance radars. A failure is recorded when it takes more than one minute to restore computer use. In every case, the mean time between failures increased significantly over the three-year period, almost doubling the time between outages. The mean time to restore service when an outage has occurred has remained relatively unchanged. For example, according to FAA data, it took 0.21 hours in 1977 to repair composite flight data processors, and 0.22 hours for the same repair work in 1980. Airport surveillance radars had mean restoration times of 1.65 and 1.79 hours in 1977 and 1980, respectively. In our judgment, it appears that ATC computer systems are becoming more--not less--reliable.

Center computer outages have been a prime target for criticism. An analysis of FAA data shows that unscheduled interruptions and outages decreased by more than half during the three-year period from 1977 to 1980. The FAA Airways System Division reviewed these data to determine whether all outages had been reported and to ascertain that none were mistakenly reported as interruptions. After comparing data from three different reporting systems over a period ranging from five months to two years, FAA concluded that the performance of enroute computers is "as claimed," and that the logs were not falsified. Nevertheless, as noted in the 1981 congressional report, **Air Traffic Computer Failures**, there are weaknesses in FAA's reporting system. We note that FAA has begun to take steps to revise its procedures for collecting and standardizing sources of performance data.

Even though ATC is a technology-intensive system, the basic principle of "see and avoid" is still used for collision avoidance. In fact, it is one of the rules of operating in the ATC system. According to FAR 91.67, "When weather conditions permit, regardless of whether an operation is conducted under Instrument Flight Rules or Visual Flight Rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft." This principle applies to aircraft operating independently of, or participating in, the ATC system.

Most people in the aviation community agree that see and avoid as a separation technique is inadequate. Visibility from the cockpit is hampered by smoke, haze, sunglare, and limitations of the human eye. Moreoever, its effectiveness as a separation method cannot be quantified. Although ALPA maintains that a third pair of eyes is needed in the cockpit to detect nearby aircraft and avert collisions, an analysis of the accident data for aircraft with two- and three-member crews does not support this contention. In addition, ALPA's and FEIA's support for a cockpit with a sidefacing engineer's panel seems inconsistent with their claims of the value of the third crew member in spotting traffic, since that configuration further removes the engineer from the area where scanning is most effective. Moreover, the sidefacing panel itself can block the view from the cockpit side window.

FAA is developing new technologies to provide further collision avoidance protection, such as Conflict Resolution, the Mode S Improved Radar Beacon System (formerly called DABS - Discrete Address Beacon System), and the Threat Alert and Collision Avoidance System (TCAS I and TCAS II). These technologies consist of both airborne and ground-based systems whereby potential conflicts are identified and solutions developed by computers in ATC towers or centers; the pilot then receives a display of instructions to avoid the conflict. In addition, the advanced versions of the airborne systems will be able to operate independent of the ground system.

Conflict Resolution is a system designed to provide the enroute radar controller with a display of possible alternatives for resolving conflicts that have been identified by a warning system called Conflict Alert. (Conflict Alert, which is already in use in all centers and in 61 terminals, warns controllers when aircraft no longer have a specified margin of separation; the controllers, in turn, issue traffic separation instructions to the pilots.) The primary objective of Conflict Resolution is to further reduce the chance of error by shortening the decision-making time in complex encounter situations. Its earliest implementation is estimated to be in the 1984-1985 time period.

FAA projects that DABS (Mode S), which will make use of automatic digital communications, will improve ATC Radar Beacon System (ATCRBS) capability significantly. The complementary Automatic Traffic Advisory and Resolution Service (ATARS) will provide collision avoidance advisories and resolution. The main purpose of DABS/ATARS is to detect traffic and to provide aircraft escape-maneuver advisories in adjoining ATC sectors.

G/A pilots question the need for DABS/ATARS. Without their voluntary participation or a rulemaking action requiring G/A aircraft to be equipped with at least a Mode C transponder, DABS/ATARS will not protect air carriers from a major aspect of the collision threat: the minimally equipped G/A aircraft. To ensure safety and enhance collision avoidance capability, the Task Force recommends that FAA expand the areas in which aircraft are required to have Mode C or DABS transponders before they may enter controlled airspace.

TCAS, which was selected by FAA on June 23, 1981, as the primary collision avoidance system, represents the newest concept in protection against mid-air collisions. TCAS I is an airborne threat alert device that will provide pilots visual or aural warnings when they are flying too close to other aircraft equipped the with same system or with TCAS II. TCAS II is a collision avoidance system that will indicate the need for vertical avoidance maneuvers even in high-density airspace. Two aircraft equipped with TCAS II will be able to detect and locate each other by bearing and altitude independent of the ground system. An aircraft equipped with TCAS II could also receive a signal from a TCAS I-equipped aircraft giving the altitude and bearing of the TCAS I aircraft. TCAS II could potentially be expanded to include horizontal maneuvers. The TCAS system will also work in conjunction with altitude-reporting ATCRBS transponders, which are already widely used and are required in many types of airspace. FAA estimates that TCAS I and TCAS II units can be in production in 36 and 48 months respectively.

In view of past situations in which ATC improvements were recommended but never implemented, ALPA has questioned FAA's commitment to developing new programs and upgrading the total ATC system. Nevertheless, the Task Force expects that significant progress will be made in new procedures, airspace configurations, and expansion of services using current-generation technology. FAA has already announced plans to conduct a complete review of the national airspace system to identify and implement changes that will promote greater efficiency for all airspace users. Based on its findings, FAA will consider plans for new TCAs and technological improvements for new locations on a case-by-case basis. The Task Force supports making funds available to accomplish FAA's objectives for continued safe operation in the ATC system.

In addition, several procedural measures that do not depend on large funding appropriations could improve the ATC system. Examples of procedural changes include isolating high-performance aircraft from the concentrated masses of smaller G/A aircraft until each category of operations is established on the final approach or is making the final approach well within the visual range of the control tower, and requiring all aircraft to use well-defined departure procedures until outside the terminal area.

Based on the evidence heard in testimony and on our independent research, the Task Force finds that:

- The ATC environment is complex and demanding. However, this complexity does not justify characterizing the environment as "hostile" and "dangerous."
- The majority of aircraft operating in the ATC system today do so with one or two crew members

in the cockpit. Over the past 15 years, two-crew member transport aircraft have accounted for an increasing share of passenger-carrying operations, and have done so with safety records essentially indistinguishable from those of three-crew member aircraft. The ATC system can equally support the safe operation of two- and three-crew member aircraft when the aircraft are properly designed for their respective crew complements.

COCKPIT SYSTEMS AND TECHNOLOGY

Since the introduction of microprocessor and display technologies in the 1970s, cockpit designs have evolved toward more fully automated, integrated systems. The most recent product of this evolutionary process, the DC-9-80, uses a digital, integrated flight guidance system, but retains the standard (electromechanical) instrumentation and layout of earlier aircraft. The manufacturers have stated that the B-757/767 and A-310 will be much further along the continuum of technological change. These aircraft will offer new modes of operation that will greatly increase the automation of flight guidance and control functions. In addition, advanced electronic displays and input devices will provide the pilot new methods for controlling the aircraft and its subsystems.

ALPA and others have raised a number of concerns regarding the impact these changes will have in new-generation aircraft. Specifically, they argue that new technology does not necessarily reduce workload (and may in fact increase certain types of workload) and is subject to increased failure.

The manufacturers have cited instances suggesting that new technology will reduce the incidence of human error and increase the precision of flight path control. Furthermore, they contend that the new technology is more reliable than the electromechanical systems it replaces.

These two basic issues--the impact of technology on the flight crew, and system reliability--were the critical questions we addressed in our review of the implications of cockpit systems and technology for crew complement certification.

IMPACT ON THE FLIGHT CREW

The impact of technology on the flight crew depends largely on how the systems in question are implemented and how the crew interacts with those systems. Any determination regarding the certification of crew complement must therefore be made in terms of a particular aircraft. We reviewed the cockpit systems of the DC-9-80, B-757/767, and A-310, and examined the planned application of technology in future aircraft. In the course of our review, we considered the implications of cockpit systems and technology for the certification of crew complement.

DC-9-80

FAA accepted the DC-9-80 as a derivative of the DC-9 series aircraft, certifying the new aircraft under an amendment to the original type certificate. Given this FAA decision, we focused on the changes introduced in the DC-9-80 compared with its predecessor, the DC-9-50.

Douglas considered two of the changes introduced in the DC-9-80--the dial-a-flap system and the stabilizer trim computer--to increase workload slightly, and the remaining changes either to reduce or have no effect on workload. In its crew complement determination, FAA considered 10 of these changes to reduce pilot workload. Nine of the changes eliminated functions previously performed by the pilots. The remaining change--replacement of the DC-9-50's autopilot, flight director, autothrottle, and speed command systems with an integrated digital flight guidance system (DFGS)--changed the tasks performed by the crew somewhat.

The DFGS in the DC-9-80 consists of two completely redundant digital computers, each of which is capable of controlling the entire system. By using prestored data and then selecting appropriate control modes, the pilot can transition from one phase of flight to another. Additional modes and capabilities over those available in the DC-9-50 are provided, in part because the DFGS incorporates a "full-time" autothrottle system which can be used throughout all phases of flight (compared to the approach-only autothrottle system in the DC-9-50).

Task changes brought about by this system were discussed by two DC-9-80 line pilots in their testimony before the Task Force, in which they noted that although the DFGS decreases "workload," monitoring is still required. This change is also reflected in the results of the time-line analysis performed by Douglas. Principally, on the basis that fewer observable tasks are required to operate the DFGS on the DC-9-80 than to operate the autopilot on the DC-9-50, Douglas concluded that workload is lower on the DC-9-80. However, Douglas concedes that the time-line technique fails to take into account mental workload.

When considered in the context of existing aircraft, especially the third-generation DC-10 and L-1011, the DFGS on the DC-9-80 appears to us to be but another step in the evolutionary development of cockpit systems. In fact, it is our impression that the manufacturer has capitalized on lessons learned from experience with earlier aircraft by incorporating various refinements in the DC-9-80 DFGS. For example, the visibility and legibility of the flight mode annunciator panel have been improved considerably. Furthermore, interlocks that preclude inadvertent pilot selection of incompatible pitch and speed modes have been designed into the DFGS. Thus, although the DFGS has brought about changes in the specific number and nature of pilot tasks, it does not appear to have brought about any fundamental change in the role of the pilots. For this reason, we conclude that the methods used to demonstrate compliance with the crew complement certification criteria were appropriate and correct for the DC-9-80.

B-757/767

Substantial controversy has arisen concerning the likely impact of the design of the two-crew member B-757/767 on crew workload and performance, and the adequacy of the measurement techniques to be employed by Boeing and FAA during type certification for assessing crew workload in these aircraft.

Boeing feels that it has judiciously employed the systems approach to design aircraft that can and should be flown by two pilots. The manufacturer believes that the required duties can be managed successfully on the two-crew member aircraft as a result of automation and simplification of aircraft systems. In fact, asserts Boeing, the two-crew member design provides automatic systems operations, control, monitoring, and status determination more reliably and more accurately than a third crew member could. Boeing also believes that automation of routine flight guidance and control tasks provides the pilot and copilot additional time for surveillance, instrument scan, and command decisions. Furthermore, Boeing feels that the operating procedures and crew training programs being developed with the airlines will ensure the safety of these aircraft in airline operations.

Based on a variety of analytical and laboratory studies conducted during the development phase of these aircraft, Boeing asserts that pilot workload in the two-crew member aircraft will be less than (or, at the very least, equivalent to) that in the B-737, the aircraft selected by Boeing as the standard for such comparisons. Boeing believes that the adequacy of its workload assessment techniques has been demonstrated by the successful operating and safety record of the B-737. Moreover, the fundamental flight crew tasks and decisions required in the B-757/767 are the same, according to Boeing, as in existing air transport aircraft. Boeing does recognize that some changes in pilot tasks will occur, but believes that the primary effect will be to provide the crew greater ease and flexibility in the timing and type of actions required.

Proponents of three-crew member aircraft accept the use of new technology in the B-757/767, but believe that it should be used only in a three-crew member configuration until more information is obtained regarding its impact on crew workload and performance. They also believe that not including a third crew member's panel has resulted in several design inadequacies that will adversely affect crew operation of aircraft subsystems. Specifically, they claim that (1) a third crew member's duties are substantially transferred to the pilot and copilot in a two-crew member design, (2) information regarding subsystem operation that is needed by the crew will not be available (or at least not continuously available) in the two-crew member design, and (3) more steps will be required to perform certain tasks with the advanced features of the B-757/767 flight management system.

ALPA and other proponents of three-crew member aircraft contend that the functions the pilots perform in a two-crew member B-757/767 will be substantially different (specifically, more mental than physical) from those performed in previous two-crew member aircraft. In view of what it regards as a change in the nature of crew workload, ALPA questions the adequacy of the methods that have been used for assessing crew workload on previous aircraft. ALPA also states that its analyses are limited because of its lack of accessibility to information on the design of the B-757/767.

In its testimony to the Task Force, Boeing outlined the updated workload assessment procedures it plans to use in the B-757/767 certification process. These include eye point-of-regard and dwell time, an expansion of the time line/task analysis program, and estimates of mental workload. Boeing also stated that its preliminary studies are only a part of the total development and certification process, and that conclusive support for its two-crew member design will not be available until simulation and flight tests are conducted.

The Task Force notes that at this stage of development of the aircraft, sufficient evidence does not exist to determine whether the new two-crew member aircraft are in compliance with all the crew size certification requirements of FAR 25.1523. We recognize that many of the specific functions performed by the B-757/767 pilots--as well as the types of errors those pilots may make--may be different from those performed in existing two-crew member airplanes. Nonetheless, there is no evidence to indicate that the differences in pilot function are substantial enough to warrant changes in the basic way Boeing plans to measure workload for purposes of crew size certification. Furthermore, there is no reason to delay certification testing of two-crew member B-757/767 aircraft pending completion of further research.

Although we have concluded that changes in cockpit technology in the new-generation aircraft do not warrant major changes in the methods for measuring workload during certification, we do recognize the importance of directing additional attention to the development and evaluation of flight crew operating procedures and flight crew training. We therefore recommend that the airlines, manufacturers, and government agencies aggressively pursue research in these areas to provide essential guidance as the new technology matures and evolves.

Future Aircraft

According to the manufacturers, cockpit designs will continue to evolve toward more automated, integrated systems, with more modes and greater capabilities. The changes that have been proposed primarily involve increased use of electronic displays and changes in the type and format of information available to the pilot. Flight navigation and guidance systems will be affected most; four-dimensional area navigation systems, global positioning systems, collision avoidance systems, and wind shear detection systems are proposed for inclusion in future aircraft. Primary flight instruments are also projected to change significantly. Systems for detecting, diagnosing, and displaying faults and warnings are also expected to be based on new technology.

The Task Force concurs with ALPA that these changes are likely to result in a significant change in the pilot's role over the next 20 years. Accordingly, we recommend that FAA and NASA aggressively pursue research to develop methods for assessing crew complement requirements for future aircraft.

RELIABILITY

ALPA and FEIA have raised the issue of reliability in the context of the crew complement controversy. Historically, FAA has considered the reliability of automated cockpit systems to be an issue in its own right and not a factor in determining crew complement. The summary report of the 1977-1978 Task Force on Crew Workload notes that the philosophy underlying the design of current aircraft and the reliability demonstrations required in the type certification process is that redundancy and provisions for backup systems must ensure that the aircraft is "fail-safe." If necessary, FAA ensures that systems are improved to achieve the fail-safe criterion. Based on careful consideration of the question of how reliability should be addressed, we agree that reliability is an issue in itself, and have treated the subject accordingly.

The reliability of aircraft systems employing new technology is being challenged by ALPA and FEIA on the basis that sophisticated technology is subject to increased failure. Specifically, ALPA and FEIA have presented the results of an analysis of FAA service difficulty reports (SDRs) purportedly showing that newer technology has a higher failure rate than older technology. ALPA also cites pilot experience to support the contention that new technology systems are less reliable in actual operation than projected by the manufacturer or FAA.

Douglas takes exception to ALPA's SDR analysis primarily on the basis that many of the differences are related to aircraft size rather than technology level. The manufacturer points out that the third-generation aircraft (B-747, DC-10, and L-1011) are all wide-bodies, while the second-generation aircraft (B-727, B-737, DC-9, and BAC-111) . are the four smallest transport aircraft. The Seattle Professional Engineering Employees Association (SPEEA) also takes exception, arguing that failure rates per flight hour are more meaningful than failure rates per departure in evaluating automation. Using average stage lengths to derive SDRs per flight hour, SPEEA concludes that the failure rates of mature systems are not higher than the rates for first-generation aircraft (B-707, B-720, DC-8, and CV-880/990).

From a technical standpoint, the Task Force believes that the SDR analysis contains too many variables to draw any meaningful conclusions regarding system reliability. The analysis performed by ALPA equates technology level with the time period in which various types of aircraft first came into service. Three generations of aircraft are used, spanning a period from 1958 to 1971. However, the data analyzed were accumulated over the time period 1974-1978. Thus, in addition to size, there is a difference in maturity level of the aircraft involved, which could have a significant effect on the data. For example, with regard to engine shutdown rates, a comparison using ALPA's approach indicates that the rate for the so-called third-generation CF-6 engine is twice that for the second-generation JT8 engine in 1976. However, in 1976, the CF-6 was only in its third full year of operation while the JT8 had been operating for 13 years. A comparison of shutdown rates on a year-by-year basis since introduction, however, indicates that over the first 8 years (the CF-6 is only in its ninth full year of operation), the CF-6 had a lower shutdown rate than the JT8 for all but one year.

Interpretation is also obscured by the fact that the systems category of the SDRs contains 14 subcategories, ranging from autoflight systems to doors. In ALPA's analysis, the resulting mixture of electronic and mechanical systems was further divided into those related to departures and those related to hours of operation. The resulting SDR rates, therefore, are generalized to the point that the reliability of any specific system (or class of system) cannot be determined.

Douglas believes that the SDR data provide no usable information regarding the advantages, disadvantages, or reliability of what ALPA considers new technology. The Task Force recognizes Douglas' position, but also understands ALPA's and FEIA's genuine concern that more sophisticated systems will be subject to more failures and that the level of reliability obtained through redundant systems will be negated if aircraft are allowed to be dispatched with backup systems inoperative. The systems that seem to be at the center of this debate are those that have been (or will be) used to reduce pilot workload in newer generation aircraft, including the flight guidance system in the DC-9-80 and the automatic flight control system in the B-757/767.

The manufacturers are confident that these new systems will be reliable. Boeing predicts that the mean time between failures (MTBF) for the electronic flight instrument system of the B-757/767 will be 1,500 hours, compared to 1,200 hours for the B-747 electromechanical system. Reliability estimates for some major B-757/767 components range from 2,000 hours MTBF for the inertial reference unit to 10,000 hours MTBF for the air data computer. These estimates are supported, in part, by experience from the B-1 program, in which measured mean time between removals (MTBR) for similar equipment compared favorably with predicted values for the B-757/767 equipment.

Douglas testified that the digital equipment on the DC-10 has exhibited excellent reliability during approximately six million hours of airline service. The manufacturer further claims significant improvements in the reliability of the flight guidance system over predecessor aircraft. According to Douglas, the probability of at least one function being inoperative on contemporary aircraft is 2.2 times greater than on the DC-9-80.

Although we cannot make a determination on whether the new technology systems will be as reliable as the manufacturers indicate, the data we have reviewed in no way suggest that they will be less reliable than the systems currently in use. Recognizing that the newer systems tend to be more complex, designers are placing added emphasis on systems architecture, ensuring that the failures of some functions do not affect the availability of other functions. In addition, the manufacturers are employing redundancy in critical areas such as the automatic flight control system to provide fail-safe or fail-operational capability.

Based on our review of the impact of design changes in the DC-9-80, B-757/767, and future aircraft on the crew, and the question of reliability, the Task Force has reached the following findings and conclusions:

- o The increased use of automation on the DC-9-80 has led to a change in the number, but not the nature, of the tasks that the pilot performs compared to the DC-9-50. Since the role of the pilot is unchanged, the Task Force concludes that the procedures for determining crew complement in the DC-9-80 were appropriate.

- o With respect to the B-757/767, the Task Force finds that although some pilot tasks will change, the techniques planned by Boeing to demonstrate compliance with crew size certification requirements are appropriate.

- o With respect to future aircraft, the Task Force believes that the nature of the pilot's tasks will continue to evolve to a point where new workload measurement techniques may be required sometime in the future. To be prepared for future certifications, the Task Force therefore recommends that FAA and NASA vigorously pursue research to develop methods for assessing crew complement requirements for future aircraft.

- o The Task Force finds no reason to believe that new technology systems will be less reliable than current systems. In any case, system reliability should be dealt with through measures other than the addition of a third crew member.

HUMAN FACTORS

Human factors questions are central to the crew complement issue. Much of the debate has focused on the methods by which pilot workload is analyzed and measured during the design and certification of new aircraft. The role of simulation, including "full-mission" simulation, in this process is also a debated topic. Other human factors issues involve questions of team and small group performance: how can effective command and leadership, crew coordination, cross-monitoring, and communication be achieved, and what are the implications for crew complement? The impact of pilot incapacitation and "see and avoid" are also important human factors questions.

WORKLOAD ANALYSIS AND MEASUREMENT

The basic question about workload measurement and analysis addressed by the Task Force was whether the techniques used to determine crew workload in the design and certification of the DC-9-80 were appropriate indicators of the workload criteria specified in Appendix D to FAR 25. We also reviewed the plans for workload analysis and measurement on the B-757/767 and A-310.

Aircraft manufacturers use a variety of approaches to determine crew workload. In the early stages of design, they frequently conduct laboratory experiments using various objective and subjective measures to assess the workload of new systems that will be used in an aircraft. During the mockup stages of design, the focus is primarily on reach, location, visibility, and ease of operation of basic controls and indicators. Task analysis/time-line techniques are also used extensively during the design and certification process. These techniques generate objective, quantitative data on the amount of physical effort required to operate the various cockpit systems. They do not measure stress or mental workload. Furthermore, the manufacturers state that there are no generally accepted, well-validated measures of such factors.

In addition to these tests, Douglas and FAA conducted a "mini-airline" evaluation of the DC-9-80. During this flight test, representative airline routes and operations were flown by Douglas and FAA pilots in order to evaluate workload in a realistic environment. The scenarios selected included a range of parameters such as time on duty, traffic density, late changes in approach procedures, various equipment and systems failures, and simulated emergency conditions, including pilot incapacitation.

The basic data produced from the mini-airline flight test consisted of audio and video tapes of cockpit operations, observer comments, flight leg record sheets, daily crew workload reports, and daily record forms. Using these report forms, the participating pilots provided ratings and comments regarding various DC-9-80 systems and workload. The pilots also submitted summary workload evaluation reports. According to Douglas, the workload assessment techniques used represented the best and most stable measures available at the time the DC-9-80 was certified.

ALPA and FEIA disagreed: they did not think Douglas' workload assessment techniques provided an accurate account of crew workload. ALPA specifically criticized the mini-airline operation, claiming that reliance on subjective opinion and task/time-line analysis can lead to inaccuracies in estimating workload because they do not address mental workload and stress factors adequately. According to ALPA, the rating scales were not constructed, administered, and analyzed properly. The use of an average workload index in analyzing the task/time-line data was also criticized. The principal purpose for conducting task/time-line analysis is to identify workload peaks, which ALPA argues would be masked by the averaging process. As an alternative, ALPA submitted to the Task Force results of a test comparing crew duties between the DC-9-80 and the DC-10, A-300-B4, and B-727-200. According to the ALPA data, which was based on duties described in aircraft operating manuals and expanded checklists, workload was significantly higher on the two-crew member aircraft than on the three-crew member aircraft.

Although there are recognized shortcomings in the techniques used by Douglas, we find that the crew duties analysis used by ALPA has even more serious deficiencies. A large proportion of duties included in the analysis occur during pre-takeoff and post-landing phases of flight and are not generally time-critical. Furthermore, a simple counting of duties cannot measure two important determinants of workload: the pacing of events and the complexity of tasks.

Based on our review of the techniques used by Douglas and FAA, the criticisms raised by ALPA and FEIA, and a survey of workload assessment methods, we conclude that the workload assessment techniques used to certify the DC-9-80 represented the state-of-the-art at that time. Although some of the criticisms of these techniques are valid, there were no other generally accepted techniques that Douglas could have been required to use. However, Douglas could have utilized any of several additional objective and subjective techniques as adjuncts to its basic tests. There is no reason to believe that the use of these techniques would have resulted in a different decision on crew complement, but the techniques could have contributed additional data that might have precluded some of the questions raised by ALPA.

We also conclude that there are no new workload measurement techniques that have been sufficiently validated to require their use in the certification of future aircraft. We note, however, that progress has been made in improving the quality of several objective and subjective measures. For example, Airbus Industrie is improving its time-line analysis techniques and subjective reporting for use during certification of the A-300 Forward Facing Crew Cockpit and A-310.

We conclude our discussion of workload with some observations of a more general nature. In reviewing the testimony and supporting documentation presented to the Task Force, we were struck with the many different uses of the word "workload." In some cases, the term is used to refer to the physical effort required to operate a subsystem, system, or the entire aircraft. In other cases, the term appears to refer more to stress due to the cognitive or mental demands placed on the flight crew by the aircraft, its systems, and the environment in which it operates. In still other cases, workload is used to refer to the cumulative effects of flying long duty days or multiple segment trips, or to the long-range effects of extended, intercontinental operations. Workload is also used to refer to handling cabin problems, spotting traffic, and other air traffic requirements.

In our view, workload is the integrated effect of all these factors. For the purposes of certification, then, assessment of workload is basically a way to determine whether there is sufficient time for the crew to accomplish all the tasks required for operating the aircraft while maintaining the required precision of flight path control under the combined demands of flight, and whether such performance is achieved without unacceptable stress. We conclude that the subjective opinions of engineering test pilots, FAA certification pilots, and line pilots may provide the best means to make this assessment. There is, after all, inherent validity in the basic process by which pilots decide that an aircraft, its systems, and its crew complement are acceptable from the point of view of system safety and efficiency. Improvements in subjective evaluation methods, combined with improved objective measures, should provide a rich source of data on how the multiple aspects of workload combine to affect performance. The Task Force strongly supports research programs to improve methods for relating various subjective and objective data to measures of system performance.

FULL-MISSION SIMULATION

Closely related to the issue of workload measurement and analysis is the role of simulation in the design and certification of new aircraft. Only a full-mission simulation 6/, ALPA and FEIA maintain, can provide the basis for evaluating the relative merits of flying with a two- or three-member crew.

Prior to certification of the DC-9-80, ALPA developed full-mission simulation scenarios and presented them to FAA with the strong recommendation that they be used during the certification process. FAA and Douglas included many of ALPA's suggested flight conditions in the mini-airline test. For a variety of reasons, including the lack of suitable simulation facilities, the complete set of scenarios was not evaluated.

In its testimony to the Task Force, ALPA recommended that full-mission simulation be required for the certification of future generation aircraft. While there is some sympathy in FAA for ALPA's position, the lack of suitable facilities again places practical constraints on the feasibility of requiring full-mission simulation.

Air carrier training programs are making increased use of a form of full-mission simulation known as LOFT. Because of its emphasis on the effective use of the aircraft, its systems, and other resources (including ATC, maintenance, dispatch, and crew coordination), LOFT is a useful tool for studying pilot/aircraft system performance during both routine and abnormal circumstances. Accordingly, the Task Force examined the potential use of full-mission simulation techniques in the design and certification process.

If simulation is considered at its most rudimentary level, aircraft manufacturers make extensive use of "paper and pencil" simulators or static mockups in preliminary cockpit design studies. As cockpit

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6/ Although the term full-mission simulation is generally associated with military operations, in the context of the crew complement controversy, it refers to the use of a training simulator with structured scenarios that incorporate many of the environmental and operational factors encountered in actual flight operations; this requires simulation of basic aircraft systems and performance, navigation aids, communications, and ATC functions.

hardware becomes available, dynamic mockups with operable controls or indicators are used. Part-task simulators represent the next stage in simulation fidelity. In practice, these vary from a fairly rudimentary representation of the cockpit and its systems to simulators that are high fidelity in terms of cockpit systems, controls, and indicators. In some cases, simulator motion and external scene visual systems are also included in these part-task simulators.

According to the manufacturers, these techniques represent the highest simulation fidelity feasible prior to completion of the certification flight test program. They contend that because various aircraft systems are modified based on information gathered during the flight certification program, the flight test must precede simulation. Any requirement to include full-mission simulation, they argue, would introduce lengthy and costly delays in the certification process. Furthermore, factors such as scanning for traffic may never be adequately evaluated in a simulator.

We concur with the manufacturers that a simulation based on the operational characteristics of the aircraft can come only relatively late in the design process. However, in view of the control that can be exercised over test conditions and the safety benefits of simulation, the Task Force recommends that aircraft manufacturers increase the use of line operations simulation scenarios in the design and certification process. We believe that data obtainable from simulation can augment and enhance the quality of the data base generated by the flight test program. In addition to the regular flight test program, Airbus Industrie is planning to have a training simulator available for the last three months of the certification program for the A-310. Although similar scenarios will be flown in both the simulator and the aircraft, Airbus Industrie plans to include more severe, higher risk (and less probable) situations in the simulator. In addition to simulator performance data, Airbus Industrie and French aviation authorities plan to have an observer record errors and provide workload assessment data.

We do not agree with the ALPA and FEIA proposal that each new aircraft be tested in both two- and three-crew member configurations. We find that the state-of-the-art of performance and workload measurement would preclude obtaining reliable results from such an approach. Many factors--including operating procedures, crew training, experience, personality traits, individual characteristics, and specific cockpit and system designs--affect pilot/system performance. It is highly unlikely that differences in performance that could be attributed to crew size alone can be measured with sufficient reliability and accuracy in any practical, feasible experiment.

COCKPIT RESOURCE MANAGEMENT

Cockpit resource management refers to the way human and technical resources are used by the flight crew. An especially important element of cockpit resource management is the pilot's ability to achieve crew integration through effective monitoring, communications, and delegation of specific tasks. ALPA and FEIA maintain that the relevant research and aviation safety data show that a cockpit crew of three is better equipped to cope with abnormal and emergency situations because of the added flexibility the third crew member provides. They argue that an analysis of ASRS data shows that a third crew member performs the important function of shielding the other crew members from various distractions. They also argue that the third crew member can assist the pilots by serving as a communications link between the cockpit and other elements of the aviation system, including the cabin crew, ATC, and maintenance operations.

The pilots and flight engineers also argue that the third crew member performs an important monitoring function and can detect and point out operational errors before they develop into an incident or accident. This role, according to these groups, will become increasingly important as the complexity of cockpit systems and the air traffic environment increases.

The manufacturers and airlines counter these arguments by contending that technology in the cockpit presently leads to underutilization of a three-member crew; this, in turn, leads to complacency, boredom, and extraneous conversation--all of which can be highly distracting. Although several accidents and incidents have occurred because of these factors, they argue that no accidents can be demonstrated conclusively to have occurred because of the absence of a third crew member.

The manufacturers and airlines also contend that research shows that smaller groups are better at problem-solving than are larger groups. They state that experience and observation show that two-member crews are more closely coordinated, and that cross-monitoring is far more effective than with a three-member crew. They conclude that a properly trained crew using appropriate cockpit procedures in an aircraft designed to be operated by two pilots can achieve a level of safety equal to or greater than that achieved with three crew members.

The Task Force finds the existing research results to be equivocal with regard to the crew complement issue. A review of psychological research conducted on small group and team performance revealed no compelling reason to favor any particular team size. Moreover, very few of these studies are directly relevant to the crew complement question. Most were conducted in the laboratory using procedures and situations that do not correspond closely with the command/subordinate relationship of the pilot and crew in either a two- or three-crew member aircraft.

With regard to the question of cross-monitoring, again the available data are equivocal. ALPA and FEIA argue that a third crew member serves a valuable monitoring purpose. However, in a study of 17 approach and landing accidents, NTSB noted that the third crew member alerted the pilot to a deviation from the flight profile in only 2 of the 12 approaches involving three-crew member aircraft. Moreover, although ALPA and FEIA cited many incident and accident reports in which the third crew member was apparently instrumental in solving a problem or avoiding an accident, the Task Force found other reports in which the actions of the third crew member appeared to contribute to the mishap.

As discussed in the Safety Record section, the Task Force agrees with ALPA's analyses of the ASRS data that showed lower reported rates of altitude and clearance deviation for three-crew member aircraft than for two-crew member aircraft. We also concur that there are fewer reports of problems associated with various operational and non-operational distractions in three-crew member aircraft. However, when these results are considered in context, we find that they do not provide conclusive evidence regarding the issue of crew complement. We note, for example, that the differences in the reported deviations are not reflected in the accident or FAR violation rates. From data and testimony presented to the Task Force, it is evident that FAA and the airlines recognize that distractions (e.g., public address announcements or meals being served while the flight crew is climbing or descending to an assigned altitude) can result in adverse situations. However, they are taking steps to reduce the number of distractions by eliminating non-operational duties for cockpit crew members. In addition, FAA has proposed amendments to the FARs to prohibit non-essential flight duties and extraneous conversation during all critical phases of flight.

On the basis of this information, we conclude that there is no advantage to any particular crew size in relation to safe and effective cockpit resource management. We also interpret incident, accident, and relevant research data to indicate that it is more difficult to achieve effective crew integration with larger crews. Distractions are undesirable no matter what the crew size and should be dealt with by instituting more effective operational controls rather than by using a larger operating crew.

PILOT INCAPACITATION

An issue that has been raised in the crew complement controversy is whether pilot incapacitation in a two-crew member aircraft represents an unacceptable hazard that could be avoided by the presence of a third crew member in the cockpit.

ALPA and FEIA argue that a major justification for having a third crew member in the cockpit is to provide backup in case of incapacitation. The additional crew member could assist in restraining or removing the incapacitated crew member and in landing the aircraft safely. They further argue that this becomes particularly important on long-haul overwater operations.

The manufacturers and airlines also recognize that flight crew incapacitation is a potential problem, but argue that its likelihood is very low, and that the hazards associated with incapacitation may be greater with a three-member crew than with a two-member crew. They contend that the incapacitation of a flight engineer can present the remaining crew with a situation that is more difficult to handle than when one of two crew members becomes incapacitated. In such a situation, the pilot or copilot has to leave the cockpit seat to restrain or remove the flight engineer and set up critical systems and controls on the engineer's panel. Furthermore, they argue, once the pilot is reseated, there is no way to operate or monitor the flight engineer's panel without moving again. The manufacturers and airlines contend that in an emergency, a one-pilot operation in a two-crew member aircraft may be a better situation than a two-pilot operation in a three-crew member aircraft because all controls and instruments are within reach or view of the remaining crew member.

To determine the frequency and severity of crew incapacitation incidents, the Task Force compiled data from NTSB (1962-1979), FAA (1970-1979, 1980, and a memorandum report Survey of Air Carrier Inflight Issues), and from Boeing (1966-1980). We identified a total of 84 incidents of in-flight crew incapacitations involving U.S. air carrier operations. Fifty-nine of these occurred during the time covered in our exposure data base (1971-1980). Of these, 49 occurred on three-crew member aircraft, and 10 on two-crew member aircraft. Three-crew member aircraft have an incapacitation rate 1.3 times higher based on hours flown, or 2.4 times higher based on departures than do two-crew member aircraft. A higher rate of incapacitation reports is to be expected for three-crew member aircraft simply because there are more crew members.

There have been no fatal accidents associated with known crew incapacitation on U.S. certified-route airline operations. However, a number of incidents occurring during critical phases of flight have been reported. Many airlines have developed training programs and operating procedures to ensure that an incapacitation will be detected by another crew member, and effective actions will be taken to land the aircraft safely. The airlines have taken other precautionary measures for handling potential incapacitation incidents. For example, crew members eat different meals to minimize the possibility that they all become ill from contaminated food. The "two-communication" rule, which requires one pilot to take over control if the remaining pilot does not respond appropriately to two verbal communications, is a further safeguard against subtle pilot incapacitation. Furthermore, FAR 121.385 requires that pilot crew members be trained to operate the flight engineer's panel in case the flight engineer becomes incapacitated.

From the data available to the Task Force, we conclude that flight crew member incapacitation represents no greater hazard or risk for two-crew member aircraft than for three-crew member aircraft in domestic flight operations. Examples of successful takeover of the aircraft by the remaining pilot following incapacitation at critical stages of the approach can be found for both size crews. Procedures and training programs appear to be effective in reducing the risk associated with incapacitation problems regardless of crew size. We recognize, however, that such procedures and training are not universally adopted, and recommend that FAA ensure that air carriers be required to provide such training.

During the course of our investigation, we also noted that the shoulder harnesses required for takeoff and landing are of the inertial reel variety. Although there are recognized problems associated with locking harnesses, we recommend that further study be directed to the design of crew restraint devices that would prevent interference with control column movement in the event of acute pilot incapacitation.

SEE AND AVOID

Despite technological developments in the ATC system, the see and avoid concept is still used for separation and collision avoidance. Furthermore, all parties involved in the crew complement controversy agree that see and avoid will continue to be an essential backup even after a reliable collision avoidance system is installed. The Task Force studied the contribution of the "third pair of eyes" to traffic avoidance with particular reference to human factors considerations.

ALPA and FEIA contend that a third crew member is needed to look out at critical times, and that this third pair of eyes has often saved aircraft from collisions. They support their argument by citing

ASRS data and other near mid-air incident reports, as well as data obtained from the United Airlines/ALPA B-737 crew complement study. We do not find the results of that study to be convincing. It is neither surprising nor significant that the third crew member spotted other traffic sooner and more often than the pilot or copilot because all crew members had a vested interest in the outcome of the test.

The manufacturers counter the ALPA and FEIA arguments by contending that the third crew member's view out of the cockpit is very restricted, and that even in the busiest phases of flight, two pilots can provide effective monitoring for other aircraft. Moreover, they argue, the potential for distraction associated with the third crew member may well offset any minor advantages.

We agree that the relatively small visual field of the third crew member seriously limits the potential contribution to overall traffic-spotting capability. However, we also note that the paper and pencil cockpit visibility studies used to support this argument underestimate the third crew member's field of view because the studies assume a fixed-eye position and do not account for head and body motion.

We conclude that whatever the advantage of the third pair of eyes, when all facts are considered, the presence of the third crew member does not enhance safety. We are particularly impressed with the safety record and the relatively low frequency of actual mid-air collisions. There are many situations where, regardless of the crew size, crew members will be unable to see and avoid other aircraft, and we fully support FAA's recently announced plans to implement electronic collision avoidance systems in the near future.

As a result of our investigation of human factors issues, the Task Force finds that:

- o The workload assessment tests used in the DC-9-80 certification were the best available techniques at the time. New tests are now becoming available, but they are still in the experimental stage and are not ready to be mandated for use in the certification process.

- o The manufacturers and FAA are making increased use of simulators in certification testing. Line operation simulation could play a useful role in the certification process, and its further development and application are encouraged.

- Cockpit resource management analysis shows that numerous distractions take place in the cockpit, regardless of crew size. Similarly, pilot incapacitation is an ever-present possibility in the cockpit, but success in dealing with it depends more on pilot training and procedures than on the number of crew members. Accident data do not support the contention that a crew of three provides an extra margin of safety in case of incapacitation.

- Although see and avoid is a basic tenet of collision avoidance, the available accident data do not support the contention that the addition of a third crew member contributes significantly to collision avoidance.

CERTIFICATION PROCESS

The certification of transport aircraft is a lengthy, complex process that begins officially when an airframe manufacturer submits an application for a type certificate, accompanied by supporting information and documentation, to FAA. Over the past few years, and especially in connection with certification of the DC-9-80 in August 1980 for operation with a two-member crew, questions and concerns have been raised regarding FAA's implementation of various aspects of the certification process. In an effort to address these concerns, the Task Force focused on three basic issues related to FAA's role in and approach to crew complement certification:

- Is the certification process, as established in the applicable legislation and regulations, adequate to ensure the safety of transport aircraft?

- Was certification of the DC-9-80 accomplished properly? Specifically, were all pertinent regulations complied with? Were adequate data required by FAA and submitted by the manufacturer? Were sufficient testing and evaluation conducted?

- Is the certification process adequate with respect to new generation aircraft? That is, is the process sufficiently responsive to accommodate aircraft that incorporate new technology, particularly the B-757/767?

FAA'S ROLE IN THE CERTIFICATION PROCESS

The FA Act is the statutory basis for ensuring the safety of civil aviation. Under Section 601 of the act, the Secretary of Transportation is directed to promote flight safety by issuing "such minimum standards governing the design, materials, workmanship, construction and performance of aircraft...as may be required in the interest of safety." The Secretary is further empowered to establish "such reasonable rules and regulations, or minimum standards, governing other practices, methods, and procedures as...necessary to provide for... safety in air commerce." 7/

7/The Secretary's duties as delineated in the FA Act are carried out by the Administrator of FAA.

Section 603 of the FA Act establishes the framework for ensuring the safety of all aspects of aircraft design, through the issuance of type, production, and airworthiness certificates.

A type certificate signifies that the design, material, specification, construction, and performance characteristics of a new aircraft meet minimum standards, rules, and regulations. A production certificate is issued to a manufacturing facility based on FAA's finding that the manufacturer's facilities, procedures, and organization are capable of producing a particular aircraft in conformance with the approved type design. Each aircraft produced in an approved production facility and in conformance with a type certificate is issued a certificate of airworthiness signifying its suitability for safe flight.

To ensure the safety of flight operations in air transportation, Section 604 of the FA Act provides for the issuance of operating certificates to air carriers. Applicants for these certificates must demonstrate their ability to conduct safe operations in accordance with the act and applicable FAA regulations and standards.

Under Section 609 of the FA Act, the Secretary may at any time reinspect aircraft and, if "he determines that safety in air commerce or air transportation and the public interest requires,...issue an order amending, modifying, suspending or revoking, in whole or part, any type certificate, production certificate, airworthiness certificate,...(or) air carrier operating certificate...."

FAA implements its responsibilities under the FA Act through FARs, which are subject to public rulemaking procedures. The FARs are codified in Title 14 of the **Code of Federal Regulations**.

The certification process begins with FAR Part 21, which sets forth the procedures through which "any interested person may apply for a type certificate." Under Section 21.17, each applicant must show that the proposed aircraft meets all applicable requirements of the regulations then in effect unless the Administrator deems otherwise or "compliance with later effective amendments (to the FARs) is elected or required...; and any special conditions prescribed by the Administrator." Special conditions are imposed when necessary to establish a level of safety equivalent to that established in the regulations.

Under Section 21.21, "an applicant is entitled to a type certificate" if the type design meets all applicable airworthiness requirements (or their equivalent) and "no feature or characteristic makes it unsafe for the category in which certification is requested." Once a type certificate is issued, changes to an aircraft may require a new type certificate, amended type certificate, or supplemental type certificate.

Section 21.19 states that, if "the Administrator finds that the proposed change in design, configuration, power...or weight is so extensive that a substantially complete investigation...is required" or the proposal involves a change in the number of engines or in the method of propulsion or principle of operation, then an application for a new type certificate is required. Any change in type design not sufficient to require application for a new type certificate under Section 21.19 results in an application for a supplemental type certificate. However, if the applicant proposing such a change is the holder of the original type certificate, that person may simply apply for an amended type certificate.

An applicant for a transport category aircraft type certificate must comply not only with the procedural requirements set forth in Part 21, but also with the airworthiness standards prescribed in Part 25.

Under Section 25.1501, an applicant must establish and conform with a set of operating limitations developed to ensure safe aircraft operation. One of the operating limitations specified pertains to crew complement. Under Section 25.1523, the applicant must establish a minimum flight crew that is sufficient for safe operation, considering the (1) workload of individual crew members; (2) accessibility and ease of operation of necessary controls by appropriate crew members; and (3) kinds of operations to which the aircraft will be subjected.

To determine compliance with Section 25.1523, FAA relies on a set of criteria presented in Appendix D to Part 25. Adopted in 1965, Appendix D enumerates the basic workload functions (e.g., flight path control, collision avoidance, navigation), workload factors (e.g., number, urgency, and complexity of operating procedures), and operating ATC environment (e.g., IFR) that FAA considers in determining whether the minimum flight crew proposed by the applicant is adequate.

The applicant seeks to demonstrate compliance with the applicable requirements of Part 25 through a combination of flight tests, simulator tests, computer analyses, and other methods. FAA then reviews, and in many cases, participates in the development of, the applicant's test procedures and methods of generating data (which are eventually submitted for approval). If the applicant meets the airworthiness standards--including those set forth in Section 25.1523 pertaining to crew complement--FAA issues a type certificate.

Each certified aircraft must have an FAA-approved airplane flight manual that delineates, in accordance with Section 25.1581, specific operating limitations, including "the number and functions of the minimum flight crew determined under FAR 25.1523." Any changes in the number of required crew members are incorporated in the aircraft flight manual.

During the type certification process, FAA uses "orders" in evaluating the aircraft design under consideration. Generally, these orders are internal instructions to FAA personnel containing methods, procedures, and advice concerning the accomplishment of various assigned tasks.

For example, FAA Order 8110.8, Engineering Flight Test Guide for Transport Category Airplanes, "...describes methods and procedures employed through the years in flight testing transport airplanes for type certification..." and "is designed to provide flight test personnel with information...to determine the airworthiness and consequently the eligibility of an airplane for a type certificate...." However, Chapter 187 of the flight test guide, titled "FAR 25 1523-Minimum Flight Crew," has not yet been prepared. FAA type certificate evaluators currently rely on past practices and the criteria presented in Appendix D of Part 25 in determining the adequacy of the applicant's proposed minimum flight crew.

After an aircraft has been issued an airworthiness certificate and readied for commercial service by an air carrier, the regulatory process focuses more on operations, as outlined in FAR Part 121.

An air carrier must obtain an operating certificate and a set of operations specifications designating the airports, routes, types of aircraft authorized for use, and any changes to the minimum crew complement determined under Section 25.1523. FAA has established, in Section 121.385, that "if a domestic air carrier is authorized to operate under IFR, or if it operates large aircraft, the minimum pilot crew is two pilots...."

Based on the language of the FA Act, FAA believes that once a regulatory standard is published, the agency's authority is limited to accepting or rejecting the design submitted by the applicant. FAA claims that it has no authority to require an applicant to submit or evaluate alternative proposals, although the agency does have the authority to prescribe the kinds of tests necessary to demonstrate compliance with the regulations. If the applicant does not meet the standards contained in Section 25.1523, then the applicant has the option of submitting additional information, redesigning the aircraft, or increasing the proposed minimum crew complement. Under Section 603 of the act, the Administrator must issue a type certificate to any applicant who meets the minimum standards contained in the FARs.

ALPA strongly disagrees with FAA's interpretation of the law, noting that Section 603 permits the Administrator to require any tests that he "deems reasonably necessary in the interest of safety," including, in ALPA's opinion, alternative crew complement evaluations.

The Task Force is of the opinion that, regardless of the extent of FAA's legal authority, the circumstances in the case of the DC-9-80 did not warrant the testing of alternative crew complement configurations. If FAA had doubts about the safety of the two-crew member configuration, the manufacturer would have had the option of addressing FAA's concerns.

Generally, the critics of FAA's certification process do not take issue with the FA Act or Part 25 of the FARs. Rather, they take exception to the manner in which the regulations, in particular Section 25.1523 and Appendix D, are implemented, claiming that crew complement evaluation is not based on specific, objective measures.

The Task Force reviewed the methods used by the manufacturer to demonstrate compliance with the regulations for the DC-9-80, and found that those methods were state-of-the-art at the time. Moreover, as noted in the Human Factors section, there are no generally accepted, specific, objective methods for measuring workload even today. Thus, subjective--albeit improved--methods, augmented by selected objective measures, will probably be the best available methods during the time of B-757/767 and A-310 certification.

Critics of the certification process feel that changes in the environment and operating conditions over a period of time are not adequately considered by FAA during its evaluation of the minimum crew required for safe operation of new aircraft, and that a periodic recertification process is required. The Task Force is of the opinion that FAA's periodic inspection of airlines to ensure compliance with FAR Part 121 (including aircraft maintenance and crew training and proficiency) is adequate to indicate any possible degradation of safety associated with crew complement. Furthermore, FAA pilots regularly observe flight crew performance during line operations.

Overall, the Task Force concludes that the existing legislation and regulations provide an adequate basis for a certification process that ensures the safety of transport aircraft.

CERTIFICATION OF DC-9-80

On August 24, 1977, Douglas filed an application for an amendment to the type certificate originally issued in November 1965 to add the model DC-9-80 as a derivative of the model DC-9 series aircraft. Since the DC-9-80 application was for an amended certificate, the original certification rules--those in effect on February 28, 1963--would remain applicable. However, FAA and Douglas agreed that the DC-9-80 certification basis would be the airworthiness standards in effect on the day of application, August 24, 1977, with certain exceptions. The airworthiness certification basis was FAR Part 25 (through amendment 40), including Appendix D. Also included were 32 exceptions, one exemption, and four special conditions related to FAR 25, covering items ranging from fasteners to fuel jettisoning and reverse thrust. None of these, however, related to the crew complement considerations included in FAR 25.1523 or Appendix D. The Task Force therefore believes that the FAA decision to certify the DC-9-80 through an amended type certificate has no particular relevance to the crew complement issue.

Over the years, the methods used by the manufacturer to assess crew complement have kept pace with the evolution of the DC-9 series aircraft.

The documented history of crew complement determination for the DC-9 series airplane began on May 20, 1963, when Douglas submitted to FAA a report containing photographs of a mockup of the two-member crew arrangement for the DC-9-10. This report constituted official notice to FAA that Douglas was seeking certification of the DC-9 with a minimum crew of two. The two-crew member capability was made possible on the DC-9 by locating all flight controls within access of either pilot, locating all indicators and the annunciator panel within view of either pilot, and simplifying and improving other systems and displays.

Two and one-half years after the original data were submitted, FAA test crews completed their evaluation and reached a final determination that the flight deck arrangement, individual crew workload, and control accessibility on the DC-9-10 were satisfactory for a two-crew member operation.

In the intervening years between certification of the DC-9-10 and DC-9-50, few cockpit changes were introduced. The series 50, however, incorporated 34 cockpit changes, eight of which were considered by FAA to reduce workload. The remainder were considered to have no impact on workload.

FAA conducted a dedicated in-flight evaluation of crew workload on the DC-9-50 with FAA test crews for a period of six days over a route simulating a typical DC-9 airline route. The test aircraft was instrumented to allow the observers to see the crew actions and hear all air/ground and intercom communications from the aircraft. Based on the results of these tests, FAA certificated the DC-9-50 for a minimum crew of two.

As in the case of the -50, the Douglas application for type certification of the DC-9-80 identified several design changes that were considered to have an impact on the flight crew. Ten improvements were considered by FAA to reduce workload from the DC-9-50. These improvements were assessed, and an overall evaluation of crew workload was performed, through a flight test program involving more than 1,000 flight hours (40 percent of which included FAA participation). Aircraft flight characteristics and crew workload were directly or indirectly considered in most of these tests.

As part of the flight tests, FAA decided that the DC-9-80 should be demonstrated in a high-density ATC environment, both day and night, accepting the weather exposure on the route during the validations and considering flight crew duty limits. A variety of airports was used, and route segments of short and intermediate stage lengths were included. To replicate the crew fatigue associated with line operation but still conform with the airline route bid concept, each crew team was scheduled to fly for three consecutive days. The scheduled crew duty times, flight times, and number of landings were planned to exceed those flown by most airlines, and to approach the limits established by FAA regulation.

After each day of flight, the pilots provided an overall evaluation of the aircraft. It was the unanimous opinion of the evaluation team that the DC-9-80 could be operated safely with a two-member crew, considering all contingencies that might reasonably be expected to occur in operational service.

The flight tests conducted for the DC-9-80 met most of ALPA's prerequisites for a comprehensive crew complement evaluation, with the major exception that FAA did not agree to a full-mission simulation. In addition, ALPA's review of the daily log sheets maintained by the participant pilots during the simulated airline operations led to different conclusions from those reached by FAA evaluators. ALPA contends that although crew workload never reached high levels on the test flight, numerous pilot errors were recorded. In its critique of the FAA decision basis for certification of the DC-9-80, ALPA notes, "If these errors were made under what is termed low workload conditions, it would be interesting to determine how many errors would result from high workload conditions."

ALPA has recommended that high crew workload conditions be examined in the context of scenarios (including a realistic ATC scenario) based on actual operating experience. Using simulators, ALPA suggests, cockpit design and operational procedures could be tailored to provide an acceptable margin of safety that would limit crew workload so that an unacceptable error rate would not be reached. ALPA argues that FAA has never conducted this kind of testing and analysis.

FAA counters that suitable simulation facilities and techniques for measuring crew workload and performance levels (error rates) are not available to satisfy ALPA's objectives.

The Task Force's review indicates that state-of-the-art techniques for workload measurement were applied in the flight test program conducted for the DC-9-80, workload was properly compared to that of the -50 series, ATC considerations were adequately incorporated, and a mini-airline test was conducted in sufficient depth to ensure that all the legal and regulatory requirements for crew complement certification were satisfied.

In testimony before the Task Force, many pilots indicated that FAA's crew complement certification methods do not adequately consider the increased crew workload caused by flying with combinations of inoperative equipment allowed by the MEL.

The MEL identifies those items that may be inoperative when an aircraft is dispatched. The fact that the equipment is inoperative does not mean that the aircraft is not airworthy. Through appropriate regulations, FAA permits dispatch with inoperative items defined in the MEL if the flight conforms to certain operating limitations.

However, some pilots have claimed that the airlines often dispatch aircraft on multiple flight segments with too many MEL items inoperative. The loss of automated equipment--equipment that has been credited with reducing workload and therefore the need for a third crew member--has been the subject of particular concern.

The MEL is developed during the demonstration of compliance with the rules of FAR Part 121. The Task Force, in discussing this issue with the manufacturers, FAA, and airlines, noted general agreement that a more thorough consideration of combinations of inoperative items should be included in the crew complement part of the aircraft certification process. Nonetheless, after reviewing the extent to which inoperative equipment was tested during the crew complement phases of certification of the DC-9-80 and considering FAA's 16 years of experience with the MEL for the DC-9 series aircraft, the Task Force finds that MEL issues were adequately addressed in the case of the DC-9-80.

Overall, the Task Force concludes that certification of the DC-9-80 was accomplished properly by FAA. The certification basis was defined based on empirical factors and technical consideration of the advanced systems involved. FAA participated extensively in the flight test program and carefully planned and executed the operational flight evaluation.

CERTIFICATION OF NEW GENERATION AIRCRAFT

Three major aircraft types are presently proposed for certification in the near future: the B-757, planned for two-crew member certification in December 1982; the B-767, planned for three-crew member certification in July 1982 and two-crew member certification in February 1983; and the A-310, planned for two-crew member certification by the French government (Direction Generale de l'Aviation Civile - DGAC) in March 1983.

FAA has indicated that it plans to approach certification of the B-757/767 in a manner similar to that used for the DC-9-80, issuing a "decision basis" document to substantiate the Administrator's decision. Beginning with the B-757/767, FAA will also publish the certification basis for each new aircraft design (or derivative) in the **Federal Register**. This approach will provide interested parties a formal opportunity to have input into the certification decision process.

The A-310 will be certified by DGAC using the minimum crew complement provisions of the European Joint Aviation Regulations, which contain a section virtually equivalent to FAR 25.1523 and Appendix D. In accordance with the provisions of the Chicago Convention and bilateral airworthiness agreements 8/, when a U.S. air carrier purchases the A-310 and proposes commercial operation, FAA will issue an airworthiness certificate unless it finds that additional conditions must be met.

As part of the certification process, the manufacturer develops flight test programs to demonstrate compliance with the applicable regulations. The proposed B-757 flight tests involve a total of 1,485 hours; the proposed B-767 flight tests, 1,351 hours; and the proposed A-310 program, 1,300 hours.

A mini-airline evaluation will be included in the B-757 flight test program to demonstrate compliance with the regulations for two-crew member certification. This evaluation will include exposure to all the ATC environments in which the aircraft can be expected to operate, as well as a broad spectrum of weather conditions.

The Task Force reviewed the certification process and the flight test validation procedures proposed for the B-757/767, and found both to be sufficiently sophisticated and comprehensive. However, we do recommend that FAA establish formal guidelines for evaluating the impact of the ATC system on crew workload. These guidelines should include specifications for flying in varied air traffic and weather situations.

New technology does not necessarily require new certification procedures. Many new systems that are introduced to improve performance, reliability, and capability can be adequately certified on the basis of existing regulations. Nevertheless, as increased levels of automation and additional digital systems are incorporated

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8/ The signatories to the Chicago Convention agreed that airworthiness certification is the responsibility of the state of registry; the bilateral agreements delineate the specific conditions under which any two countries agree to accept each other's "type" or "airworthiness" decision.

in cockpit designs, it is incumbent upon FAA to direct particular attention to the impact of technology on flight deck operations and thus crew complement. Special consideration should be given to the areas of software verification and reliability, as well as human factors evaluation techniques. FAA may choose to enhance its in-house capability in these disciplines or to identify outside expertise, independent of the airline industry, to which FAA would have ready access. This would ensure FAA's ability to exercise final technical judgment in cases where all interested parties are required to work together to develop new, appropriate certification criteria.

During development flight testing, the manufacturers invite customer pilots, on an informal basis, to fly on some test flights. The Task Force heard considerable testimony indicating that several aspects of new aircraft certification, such as crew procedures, workload evaluation, and training requirements, would be enhanced by augmenting FAA certification teams with qualified line pilots. We agree that FAA should establish a process to include this type of pilot input. Airline pilots could work with FAA for specified periods using a procedure along the lines of the current DER process.

Overall, the Task Force finds that the established process, improved and strengthened as recommended, will ensure proper certification of the B-757 and B-767, and proper review of the certification of such foreign-made aircraft as the A-310, from the standpoint of crew complement.

Based on the evidence presented by the various parties as well as independent investigation, the Task Force concludes that:

- o Existing legislation and regulations provide an adequate basis for a certification process that ensures the safety of transport aircraft.
- o Certification of the DC-9-80 was carried out properly with regard to crew complement. State-of-the-art techniques for workload measurement were applied, workload was properly compared to that of the -50 series, ATC considerations were adequately incorporated, and a mini-airline test was conducted in sufficient depth to ensure that all the legal and regulatory requirements for crew complement certification were satisfied.
- o The established process, improved and strengthened as recommended, will ensure proper certification of the B-757 and B-767, and proper review of the certification of such foreign-made aircraft as the A-310, from the standpoint of crew complement.

PRESIDENTIAL CORRESPONDENCE ESTABLISHING TASK FORCE

THE WHITE HOUSE

WASHINGTON

March 5, 1981

Dear Dr. McLucas:

It is my pleasure to inform you that, upon the recommendation of the Secretary of Transportation, I have appointed you to a special task force of technical experts to examine a pressing problem of aviation safety. The task force, known as the President's Task Force on Aircraft Crew Complement, will examine the issue of flight crew size for the "new generation" of commercial airlines. A description of the task force and of its responsibilities is enclosed. You should coordinate your activities through the Office of the Secretary of Transportation.

I very much appreciate your willingness to assist in this matter and wish you success in your task.

Sincerely,

Ronald Reagan

Dr. John L. McLucas
President
Comsat World Systems Division
950 L'Enfant Plaza
Washington, D.C. 20024

THE WHITE HOUSE

WASHINGTON

March 5, 1981

Dear Mr. Drinkwater:

It is my pleasure to inform you that, upon the recommendation of the Secretary of Transportation, I have appointed you to a special task force of technical experts to examine a pressing problem of aviation safety. The task force, known as the President's Task Force on Aircraft Crew Complement, will examine the issue of flight crew size for the "new generation" of commercial airlines. A description of the task force and of its responsibilities is enclosed. You should coordinate your activities through the Office of the Secretary of Transportation.

I very much appreciate your willingness to assist in this matter and wish you success in your task.

Sincerely,

Ronald Reagan

Mr. Fred J. Drinkwater III
Chief
Aircraft Operations Division
National Aeronautics
and Space Administration
Ames Research Center
Moffett Field, California 94035

THE WHITE HOUSE

WASHINGTON

March 5, 1981

Dear General Leaf:

It is my pleasure to inform you that, upon the recommendation of the Secretary of Transportation, I have appointed you to a special task force of technical experts to examine a pressing problem of aviation safety. The task force, known as the President's Task Force on Aircraft Crew Complement, will examine the issue of flight crew size for the "new generation" of commercial airlines. A description of the task force and of its responsibilities is enclosed. You should coordinate your activities through the Office of the Secretary of Transportation.

I very much appreciate your willingness to assist in this matter and wish you success in your task.

Sincerely,

Ronald Reagan

Lieutenant General Howard Leaf, USAF
Inspector General
The Pentagon
Washington, D.C. 20330

ESTABLISHMENT OF TASK FORCE ON AIRCRAFT CREW COMPLEMENT

1. FINDINGS AND BACKGROUND -- The United States has the safest aviation system in the world. The President and the Secretary of Transportation are determined to maintain this outstanding record, both for the benefit of the American public and for those who work in the aviation industry.

In 1980, the Federal Aviation Administration certificated the DC-9-80 for operation with a minimum crew of two persons. In view of the continuing and anticipated growth in aviation travel and the need to maintain safety in such an environment, I have decided to ask for a review of this decision and for recommendations concerning the use of two-person crews for the proposed Boeing 757 and 767 and other 'new generation' commercial jet aircraft. Ordinarily, such questions would be addressed by the Federal Aviation Administration; that agency, however, at present lacks an Administrator and Deputy Administrator.

2. THREE-PERSON TASK FORCE -- In light of these particular facts and of the commitment to reaffirm the maintenance of aviation safety, a three-person task force is hereby established as follows:

a. Membership. The following three impartial experts shall constitute the membership of the task force:

1. John McLucas, Chair
2. Fred J. Drinkwater III
3. Lieutenant General Howard Leaf, U.S. Air Force

b. Duties. Within 120 days of its establishment, the task force shall report to the President and the Secretary of Transportation its recommendation whether operation of the 'new generation' of commercial jet transport aircraft by two-person crews is safe and certification of such aircraft is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety.

c. Procedures. In conducting its review, the task force may use such procedures as it determines necessary but, to the extent feasible, should utilize an exploratory and non-adversary process to ensure the timely completion of its task. The task force is authorized to hold such public hearings and to hear such witnesses as it may deem appropriate, to meet with the parties, and make such interim recommendations and adopt such interim procedures as seem to it useful. Since the DC-9-80 is already in production, the task force shall, to the extent feasible, give first priority to its review of certification for this aircraft.

d. Support. All cost to support the task force shall be provided by the Department of Transportation from funds already appropriated to the Department.

e. Cooperation. All executive departments and agencies of the Federal Government, especially the Department of Transportation, Department of

Defense, and National Aeronautics and Space Administration, shall cooperate with the task force and furnish to it such information and assistance, not inconsistent with law, as it may require in the performance of its duties.

f. Duration. Sixty days after delivery of the report, the task force shall cease to exist.

FEDERAL REGISTER NOTICE OF PUBLIC HEARINGS

PRESIDENT'S TASK FORCE ON AIRCRAFT CREW COMPLEMENT

Public Hearing and Request for Public Comment

AGENCY: President's Task Force on Aircraft Crew Complement.

ACTION: Notice of public hearing and request for public comment.

SUMMARY: The President has established a Task Force to examine certain issues relating to the certification of the "new generation" of commercial airliners. The Task Force will be holding public hearings and receiving public comment on the issues before it.

DATES: *Public hearings:* The weeks of May 11 and 18, and May 27, 28, and 29, 1981 in Room 2230, Department of Transportation Building, 400 Seventh Street SW., Washington, D.C., 9:30 a.m. to 4:30 p.m. local time.

Deadline for requests to speak at first hearing: April 20, 1981.

Deadline for submission of written presentation by those speaking at the first public hearing: May 4, 1981.

Deadline for requests to speak at rebuttal hearing: May 22, 1981.

Deadline for submission of written comments: June 3, 1981.

ADDRESS: All correspondence should be sent to The President's Task Force on Aircraft Crew Complement, Room 7405, 400 Seventh Street SW., Washington, D.C. 20590.

FOR FURTHER INFORMATION CONTACT: Jack Stempler, Counsel to the Task Force, (202) 426-4869.

SUPPLEMENTARY INFORMATION:

Background

In 1980, the Department of Transportation's Federal Aviation Administration (FAA) approved operation of the McDonnell Douglas DC-9-80 commercial airliner with a cockpit crew of two persons, despite the contentions by some that operation of that aircraft requires a cockpit crew of three persons. Controversy over this issue of crew complement has continued and been broadened to include the Boeing 757 and 767 and other commercial airliners currently under development.

In response to this controversy, Secretary of Transportation Drew Lewis asked the President to establish an impartial panel of experts to examine the question. This the President did on March 5, 1981, the text of the President's Memorandum establishing the Task Force appears below. The members of the Task Force appointed by the President are Dr. John L. McLucas, Chairman, formerly Secretary of the Air Force and FAA Administrator; Fred Drinkwater, Chief of the Aircraft Operations Division of the National Aeronautics and Space Administration Ames Research Center; and Lieutenant General Howard Leaf, Inspector General of the Air Force.

The Task Force's report to the President and to Secretary Lewis is due July 3, 1981; as part of the deliberations leading to that report, the Task Force will be accepting written comments from the public and holding a set of public hearings. Persons wishing to submit written comments on the issues set forth in the President's Memorandum should do so to the Task Force at the address shown above. If possible, please submit three copies. Please put on the envelope the words "PUBLIC COMMENT". The deadline date for receiving these comments is June 3, 1981.

Hearing Procedures

A set of two public hearings will be held in Washington, D.C. in May 1981. The first hearing is designed to permit interested persons to present their views to the Task Force. The second hearing is designed to permit persons to respond to points raised by others at the first hearing.

The first hearing will be held the weeks of Monday, May 11, and Monday, May 18, 1981, from 9:30 a.m. to 4:30 p.m. each day, with a break from 12:30 to 1:30 p.m. The second hearing will be held Wednesday, Thursday, and Friday, May 27, 28, and 29 1981, on the same time schedule. The ten days of the first hearing will be divided fairly among persons expressing an interest in participating; the division will be based on the Task Force's appraisal of the information provided with the request to speak and on a judgement by the Task Force of its need and desire to question a prospective speaker on the issues in the President's Memorandum. The Task Force is especially interested in the views of aviation safety experts who can contribute to an understanding of the technical issues involved.

The second hearing is reserved for opportunities for those who participated in the first hearing to rebut presentations given by others in the first hearing. The three days of rebuttal hearings will be fairly divided among those desiring to present rebuttal testimony.

Persons wishing to speak at the first hearing should send a request to the Task Force at the above address. Please put on the envelope the words "PUBLIC HEARING REQUEST" and include the following information:

1. Name.
2. Business address.
3. Telephone number during normal working hours.
4. Capacity in which presentation will be made (i.e., public official, organization representative, knowledgeable citizen).
5. Basic position on the issues set forth in the President's Memorandum.
6. Time desired.

Requests to speak at the first hearing must be received not later than Monday, April 20. During the week of April 20, persons who will be speaking at the first hearing will be contacted by the Task Force for purposes of scheduling and other arrangements. To aid the members of the Task Force in preparing for the first hearing, it is advisable that, to the greatest extent possible, those making presentations at the first hearing submit, by Monday, May 4, 1981, four copies of their presentations and of any studies, charts, graphs, etc., to be used in the presentations to the Task Force; however, the Task Force will not refuse to consider materials and evidence which is not submitted in advance. Please put on the envelope the words "PUBLIC HEARING PRESENTATION". To increase the time for the Task Force to ask questions of speakers, speakers are strongly urged, but not required, to summarize their written presentations, rather than read them, at the hearing.

To facilitate arrangement of the rebuttal hearing, speakers at the first hearing who wish to speak at the rebuttal hearing must notify the Task Force not later than Friday, May 22.

The following procedures will apply to the conduct of the hearings.

1. The hearings will be "exploratory and non-adversary" in nature, as provided in the President's Memorandum, and will be conducted by the Chairman of the Task Force. Questions of any speaker will be asked only by the members of the Task Force, except that—

(a) with the permission of the Chairman, questions of a speaker may be asked by staff aides to the Task Force, and

(b) questions of a speaker may be asked by that speaker's own representative or counsel.

2. The Task Force reserves the right to determine the persons to be heard at the hearings and to schedule the order and duration of their presentations. The Chairman may accelerate the agenda on any day of the hearings to enable early adjournment if the progress of the

hearing is more expeditious than planned.

3. The hearings will be recorded. Any person desiring printed transcripts of the hearings must contact the reporter directly.

4. Repetitious presentations will not be permitted.

All materials submitted in response to this notice, except proprietary information, will be available for public inspection and copying at the Task Force's offices between 9:00 a.m. and 5:30 p.m. local time, Monday through Friday except Federal holidays.

Issued in Washington, D.C., on April 2, 1981.

Robert B. Schwartz,

Executive Director.

Appendix

In a memorandum for the Secretary of Transportation on March 5, 1981, the President stated:

"In view of the continuing and anticipated growth in aviation travel and the need to maintain safety in such an environment, I am creating the President's Task Force on Aircraft Crew Complement to review the 1980 Federal Aviation Administration certification of the DC-9-80 for operation with the minimum crew of two persons.

"I have asked John McLucas to serve as Chairman of the Task Force with Fred J. Drinkwater III and Lieutenant General Howard Leaf, U.S. Air Force, serving as members.

"The attached material provides further details on the background, membership, procedures, support and cooperation appropriate for the Task Force operation.

"I look forward to receiving the report of the Task Force at the earliest possible date.

"Establishment of Task Force on Aircraft Crew Complement

"1. *Findings and Background*—The United States has the safest aviation system in the world. The President and the Secretary of Transportation are determined to maintain this outstanding record, both for the benefit of the American public and for those who work in the aviation industry.

"In 1980, the Federal Aviation Administration certificated the DC-9-80 for operation with a minimum crew of two persons. In view of the continuing and anticipated growth in aviation travel and the need to maintain safety in such an environment, I have decided to ask for a review of this decision and for recommendations concerning the use of two-person crews for the proposed Boeing 757 and 767 and other 'new generation' commercial jet aircraft. Ordinarily, such questions would be addressed by the Federal Aviation Administration; that agency, however, at present lacks an Administrator and Deputy Administrator.

"2. *Three-Person Task Force*—In light of these particular facts and of the commitment to reaffirm the maintenance of aviation safety, a three-person task force is hereby established as follows:

"a. *Membership.* The following three impartial experts shall constitute the membership of the task force:

1. John McLucas, Chair
2. Fred J. Drinkwater III
3. Lieutenant General Howard Leaf, U.S. Air Force

"b. *Duties.* Within 120 days of its establishment, the task force shall report to the President and the Secretary of Transportation its recommendation whether operation of the 'new generation' of commercial jet transport aircraft by two-person crews is safe and certification of such aircraft is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety.

"c. *Procedures.* In conducting its review, the task force may use such procedures as it determines necessary but, to the extent feasible, should utilize an exploratory and non-adversary process to ensure the timely completion of its task. The task force is authorized to hold such public hearings and to hear such witnesses as it may deem appropriate, to meet with the parties, and make such interim recommendations and adopt such interim procedures as seem to it useful. Since the DC-9-80 is already in production, the task force shall, to the extent feasible, give first priority to its review of certification for this aircraft.

"d. *Support.* All cost to support the task force shall be provided by the Department of Transportation from funds already appropriated to the Department.

"e. *Cooperation.* All executive departments and agencies of the Federal Government, especially the Department of Transportation, Department of Defense, and National Aeronautics and Space Administration, shall cooperate with the task force and furnish to it such information and assistance, not inconsistent with law, as it may require in the performance of its duties.

"f. *Duration.* Sixty days after delivery of the report, the task force shall cease to exist."

[FR Doc. 81-10499 Filed 4-3-81; 8:29 am]

BILLING CODE 4910-62-M

Appendix C

PARTIES PARTICIPATING IN PUBLIC HEARINGS

Testimony was presented by:

Air California
Air Line Pilots Association, International
Air Transport Association of America
Allied Pilots Association
Boeing Commercial Airplane Company
Flight Engineers' International Association
Hawaiian Airlines
Lufthansa German Airlines
McDonnell Douglas Corporation
Pacific Southwest Airlines
Republic Airlines
Seattle Professional Engineering Employees Association
Southwest Airlines Pilots Association
Southwest Flight Crew Association
Swissair, Swiss Air Transport Company, Ltd.
Major Gen. Clifton von Kann (USA Ret.)

In addition, formal comments were submitted by:

Airbus Industrie
Aloha Airlines
Austrian Airlines
Britannia Airways
International Federation of Air Line Pilots Association

BIOGRAPHIES OF TASK FORCE MEMBERS AND LIST OF STAFF

TASK FORCE MEMBERS

Dr. John L. McLucas. Dr. McLucas is President of the World Systems Division of Communications Satellite Corporation (COMSAT). He formerly served as Administrator of FAA and as Secretary of USAF. Previously, Dr. McLucas was President and Chief Executive Officer of the MITRE Corporation, and Assistant Secretary General of NATO for Scientific Affairs.

Fred J. Drinkwater III. Mr. Drinkwater is Chief of the Aircraft Operations Division at the Ames Research Center of NASA, and a Colonel in the Marine Corps Reserve. He has 15 years experience as an aircraft commander flying large jet transports in both domestic and international operations. Mr. Drinkwater's awards include the Distinguished Flying Cross, the AIAA Octave Chanute Award, and the Burroughs Trophy for test pilots.

Lieutenant General Howard W. Leaf. General Leaf is Inspector General of USAF. He has had extensive experience as a jet pilot and test pilot for USAF. General Leaf's decorations include the Distinguished Service Medal, Silver Star, Legion of Merit, and Distinguished Flying Cross. He was previously Commander of the Air Force Test and Evaluation Center at Kirtland Air Force Base, New Mexico.

EXECUTIVE DIRECTOR

Robert B. Schwartz - Vice President, COMSAT

LEGAL COUNSEL

Jack L. Stempler - Former Assistant to the Secretary of Defense (Legislative Affairs) and General Counsel, USAF

Legal Assistant

Maj. Paul _. Black - Chief, Fiscal Law Branch, General Law Division, Office of the Judge Advocate General, USAF

TECHNICAL STAFF

Technical Director

William S. Aiken, Jr. - Director, Aeronautical Systems Division, Office of Aeronautics and Space Technology, NASA

Assistant Technical Directors

Col. Charles H. Hausenfleck - Vice Commander, Air Force Test and Evaluation Center, Kirtland AFB, New Mexico

Dr. John K. Lauber - Research Scientist, Man-Vehicle Systems Research Division, NASA Ames Research Center

Safety Record Panel

Col. Roy M. Giles, Jr. - Chief, Bomber/Transport Branch, Flight Safety Division, Directorate of Safety, Air Force Inspection and Safety Center, Norton AFB, California

Maj. Charles C. Daniels - Analyst, Air Force Studies and Analyses, Office of External Affairs

Lt. Col. James I. Miholick - Chief, Research Analysis Branch, Air Force Inspection and Safety Center, Norton AFB, California

Maj. Maxie J. Peterson - Research Analysis Branch, Air Force Inspection and Safety Center, Norton AFB, California

Richard F. Porter - Principal Research Scientist, Space Systems and Applications Section, Defense and Space Systems Department, Battelle Columbus Laboratories

Maj. Charles L. Van Nostrand - Assistant Director of Compensation Directorate, Office of Assistant Secretary of Defense for Manpower, Reserve Affairs and Logistics

---

Panel Leader

Air Traffic Environment Panel

James R. Banks	-	Civilian Air Traffic Control and Airspace Consultant to Air Force Communications Command, Scott AFB, Illinois
Maj. Joseph R. Yadouga	-	Operational Evaluation Procedures Officer, Scott AFB, Illinois

Cockpit Systems and Technology Panel

James R. Kelly	-	NASA/FAA CDTI Program, NASA Langley Research Center
Dr. Deborah Boehm-Davis	-	Research Psychologist, Man-Vehicle Systems Research Division, NASA Ames Research Center
David E. Frearson	-	Flight Dynamics Laboratory, Wright Patterson AFB, Ohio
Dr. Jack Shelnutt	-	Project Director, Seville Research Corporation
Maj. Edward White	-	Operations Officer, 11th AASq (MAC), USAF

Human Factors Panel

Dr. John K. Lauber	-	Research Scientist, Man-Vehicle Systems Research Division, NASA Ames Research Center
Lt. Col. Robert O'Donnell, Ph.D.	-	Air Force Aerospace Medical Research Laboratory, USAF
Dr. Richard J. Schiffler	-	Chief, Human Factors Branch, Aeronautical System Division, Wright Patterson AFB, Ohio
Amos A. Spady, Jr.	-	Flight Management Branch, NASA Langley Research Center

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Panel Leaders

Certification Process Panel

Herbert A. Hutchinson	- Chief, Flight Technology Division, ASD Deputy for Engineering, Wright Patterson AFB
Richard P. Krinsky	- Legal research and data analysis, U.S. Department of Defense
Lt. Col. James Pyke	- Director of Operations, B-747, Offutt AFB, Nebraska
Thomas C. West	- Manager, Aviation Safety Office of Chief Engineer, NASA

CONSULTANTS

Charles Anderson	- Former Deputy Chief Counsel, FAA and U.S. Coast Guard
Charles O. Cary	- Director of International Studies, Flight Transportation Laboratory, Massachusetts Institute of Technology
William J. Cox	- Aviation consultant
Emmett DeAvies	- Colonel, USAF (Retired)
Bert Z. Goodwin	- Professor of Law, Valparaiso University
E. Gene Lyman	- Aviation consultant
C. O. Miller	- President, Systems Safety, Inc.

Panel Leaders

WRITERS

Jane J. Stein	-	Science journalist
Myra C. Strauss	-	Editor/writer on policy and technology issues

EXECUTIVE OFFICER

Maj. George Bennett	-	Headquarters, USAF

EXECUTIVE SECRETARY

Betty M. Glazer

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Debra A. Flottman
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Ethel C. Hayden
Dale V. Holmes
Joyce E. Merritt
Phyllis E. Wallace
Kaye M. Wood

CHRONOLOGY OF THE CREW COMPLEMENT CONTROVERSY

1931: Federal regulations required a copilot on air transports that had (1) a capacity of 15 passengers or more, or (2) a gross weight of 15,000 pounds or more. Few of the air transports of that era (mainly Fokker and Ford trimotors) met these specifications; thus, the vast majority of aircraft providing passenger service operated with only one pilot in the cockpit.

1933: With the introduction of the B-247 and the DC-2, a two-member crew came into general use in domestic air passenger service. Pan American began carrying a mechanic in addition to the pilot and copilot on some of its Fokker aircraft, to make repairs in-flight or at outlying air stations.

1935: Pan Am included a flight engineer--a person holding a federal mechanic's rating--as a member of the flight crew on its Clipper flying boats, and a formal flight engineer station was provided on the Martin M-130, the famous China Clipper.

1940: The B-307 Stratoliner, the first transport with four engines and a pressurized cabin, entered domestic passenger service with three persons in the cockpit, although the aircraft had been certified for operation with a minimum cockpit crew of two.

1941-
1945: During World War II, the military services assigned a flight engineer to four-engine piston aircraft (e.g., C-54, the military version of the DC-4) to handle repairs at outlying air stations. After the war, the airlines converted the cockpits of their C-54s for civilian use with a two-member crew.

1945: CAB adopted a rule requiring a flight engineer on scheduled international flights when the design of the aircraft used or the type was such as to require engineer personnel.

1946: The Lockheed Constellation, designed and built with a cockpit position for a flight engineer, was introduced into commercial service.

1947: The DC-6 entered airline service with a cockpit designed for a two-member crew. At the same time, Boeing was developing its B-377 for either a two- or three-member crew, depending on an airline's preference.

In June, President Harry S. Truman, reacting to a series of air transport accidents involving four-engine aircraft, appointed a Special Board of Inquiry on Air Safety to investigate "the whole problem of air transport safety in the United States."

In October, on the recommendation of the Special Board, CAB held hearings on the question of crew complement. ALPA and the flight engineers took the position that a third crew member was needed in the cockpit to help deal with increased air traffic, the complexity of four-engine aircraft, the need for constant radio communication, and the increasing difficulty of navigational problems. All these factors were cited as increasing pilot fatigue and thus the possibility of accidents.

Except Lockheed, which had designed the Constellation for a three-member crew, the manufacturers opposed adding another member to the cockpit crew. The Air Transport Association also opposed adding a third member. Representatives of the airlines pointed out that none of the duties that flight engineers had carried out in the past (e.g., repairing and servicing aircraft at isolated or inadequately staffed stations, controlling engine power, monitoring fuel consumption) was still required on domestic runs. Only Eastern and TWA, which had committed themselves to the three-member crew Constellation, favored adding a flight engineer.

1948: Citing the size and complexity of the DC-6 and B-377, and the DC-4 in certain over water flights, CAB issued a rule requiring that all transport aircraft certified for a takeoff weight of more than 80,000 pounds carry a flight engineer in the cockpit.

1957-
1958: In accordance with the 80,000-pound rule, first-generation jet transports (the B-707 and DC-8) were certified for operation with a minimum crew of three members. For military versions and foreign flag carriers, the third position was not included.

1961: The National Mediation Board settled, in favor of pilots, a dispute with flight engineers over occupancy of the third seat. Although limited to a single airline, this decision prompted labor actions at other airlines, which in turn led to the appointment of a Presidential commission to determine the rights of the respective unions.

1964: In the **Jet Transport Cockpit Study**, CAB concluded that the minimum flight crew determination should be based on operational complexity and resulting workload.

1965: In April, FAA eliminated the 80,000-pound rule and, for aircraft certified after January 1, 1964, substituted the criteria for the minimum crew complement determination set forth in Part 25 of the FARs.

FAA certified the DC-9 for operation with a minimum crew of two members and also approved the two-crew member BAC-111.

1967: The B-737 was certified with a two-member crew configuration.

1968-
1970: Following an extended evaluation, involving United Air Lines, of whether the B-737 should be flown with two crew members as certified, or three as proposed by pilots, federal arbitrators found that, while the former should ultimately be possible, the latter would contribute to safety during the aircraft's introductory period.

1970: A federal arbitration panel handed down a decision establishing a three-member crew on United's B-737 flights for the duration of the next union contract. Although the decision applied only to United, it influenced Western, Wien, and Frontier in accepting a three-member cockpit crew on their B-737s.

1971: A federal arbitrator, ruling in a dispute between Aloha Airlines and ALPA, approved a two-member crew for Aloha's B-737 flights, citing the low-density, fair-weather conditions under which Aloha operated. The arbitrator, however, endorsed a three-member crew for other B-737 operations in the United States.

1973: A federal arbitrator, ruling in a dispute between Wien and ALPA, approved a three-member crew complement for

Wien's B-737 flights. The arbitrator, citing the United and Aloha decisions, concluded that Wien's operating conditions more closely resembled United's than Aloha's.

1976: The pilots of Frontier Airlines accepted a company contract eliminating the third pilot from the crew of the B-737.

1977: The pilots of Wien went on strike when the company decided to reduce the B-737 cockpit crew to two.

1979: A Presidential Emergency Board created by President Jimmy Carter settled the strike between Wien and its pilots by bringing the parties to accept a two-member crew for B-737 operations. This settlement left only United and Western among U.S. airlines with a three-member crew for the B-737.

1980: FAA certified the DC-9-80 for operation with a two-member crew and Boeing presented plans for flight decks accommodating two-member crews for its new generation B-757 and B-767 jets (although the first series of B-767s would be equipped for three crew members).

1981: The President's Task Force on Aircraft Crew Complement was established by President Ronald Reagan to review the DC-9-80 crew complement determination and recommend whether operation of the "new generation" of commercial jet aircraft by two crew members is safe and consistent with FAA's certification mandate.

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