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AIRCRAFT MANUFACTURER'S AIR SAFETY PROGRAM — THE SST SYSTEM SAFETY PROGRAM

BY CHARLES B. STEWART†

I. INTRODUCTION

THE SUBJECT of my presentation is listed on your agenda as *Aircraft Manufacturer's Air Safety Program*. I would like to add a subtitle, *The SST System Safety Program*. My reason for doing so is that my job has been to assist in the development and integration of that program, and it is, therefore, the one about which I can talk most knowledgeably. Before I describe the salient features of this program, I would like to set a background and attempt to develop a proper perspective for the subject of the airplane manufacturer and safety by discussing very briefly two general topics under the headings of history and the systems aspect of commercial air transportation.

II. AVIATION HISTORICALLY—GLAMOROUS AND DANGEROUS

When I entered the Air Corps Flying School in 1936, aviation was still emerging from its infancy. The age of the barnstormer and the dashing aviator with leather helmet, goggles, and silk scarf had not yet faded. Aviation was a glamorous and dangerous enterprise, and I suspect it was this aspect of it that provided a major attraction for me and a majority of my colleagues. The Air Corps had no safety officers in those days.

You have heard many times how Hap Arnold, during World War II, was faced with the realization that the Army Air Forces were losing more planes due to training and non-combat accidents than they were due to enemy action and how he ordered the initiation of flying safety activities. You have probably seen charts depicting the significant improvements in the Air Force's accident record since that time.

On the other hand, during the period of time between the mid-1930's and initiation of Air Force safety programs, the commercial air transportation industry had made the transition from the era of barnstorming glamor to the era of well-established, dependable civil air transport service. This transition was not made, and could not have been made, by the helmeted dare-devil type. His pioneering had demonstrated the feasibility, but the transition was made by hard-headed engineers and businessmen who were well aware that they would not remain in business very long unless their product and the service it provided demonstrated an acceptable level of safety. Long before Hap Arnold initiated safety programs to conserve his combat capability, the airplane manufacturers and the air-

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lines had recognized implicitly that safety and dependability were the chief elements of the success of their products and their services. In recent years, the Air Force and other government agencies may have pioneered in the formalization and systemization of safety programs; however, they cannot rightfully claim to have been the first to make safety a primary goal.

III. THE SYSTEM IMPACT

The next point I would like to cover in order to place the safety problem in perspective concerns the system aspect of commercial air transportation. One of the greatest testimonials to man's technological progress in recent years is the worldwide air transportation system as it exists today. Outside of a few visionaries, such as Jules Verne and Alfred Tennyson, who, even before the Wright Brothers' first flight at Kitty Hawk, foresaw "the heavens fill[ed] with commerce, argosies of magic sails," I do not believe that there were many men around the turn of the century who seriously forecast such things as today's John F. Kennedy-International Airport or Los Angeles International Airport, a modern FAA air route traffic control center, or a Boeing intercontinental 707 carrying well over a hundred people non-stop New York to Paris in less than eight hours.

This worldwide network is a vast and complex system, consisting of many and varied elements. The central element, of course, is the airplane. The airplane is only one element, however. Other significant elements include: the flight crew who operate the airplane; the natural environment in which the airplane operates; the navigation, weather, and traffic control systems and advisory services; the airports and airport services; the maintenance crews and facilities; and the many passenger and cargo supporting services. Each of these elements of the system is itself complex and consists of many sub-elements. One important sub-element common to most of these system elements is the selection, training, and performance of the people who operate them or within them.

All of these elements and sub-elements of the system have a bearing on the safety of the airplane. Some are more important in this regard than others, but all are involved. Thus, we cannot merely talk about the safety of an airplane. We must at all times remember that we are talking about the safety of a system.

IV. THE ROLE OF AVIATION ORGANIZATIONS

With this brief discussion of history and the air transportation system in mind, I would like now to pose the following question:

What is the role of the manufacturer of the airplane in the safety of the air transportation system?

This question can be answered in the negative sense by listing all of the many elements of the system over which the airplane manufacturer has no control, such as the selection, training, and performance of the operators, the installation and operation of the air traffic control system, and so forth. However, as we all know, a negative approach is seldom constructive.

A positive answer to the question is that the airplane manufacturer must design and build his vehicle with full awareness of the part it plays in the system and the many interfaces it possesses with the other system elements. His objective is to design the airplane so that it is compatible with the system and contributes to the safety of the system. This view of the role of the manufacturer is the one that The Boeing Company has held for many years. The company is proud of its history of producing advanced airplanes for the world's commercial airlines and of the many new ideas which have been introduced on its airplanes to increase performance, promote air traffic growth, and, particularly, increase safety.

There are, of course, in addition to the manufacturer, many agencies and organizations vitally interested in and directly concerned with the safety of the air transportation system. The Federal Aviation Administration is the agency that reviews the overall system safety requirements and, on behalf of the public, sets forth the appropriate safety regulations. In addition, the airlines and the Air Transport Association have a direct and economic interest in safety. Pilots' associations, such as ALPA, have a rather intense personal interest in safety. And, there are many semi-public and private organizations, such as the Flight Safety Foundation, who study the problems industriously and productively.

Each of these organizations must remain abreast of what the others are doing. While the FAA, more nearly than any other, has the role of overall supervisor, each should be constantly aware of the problems of the entire system. If this is done consistently, we should seldom be confronted with a problem that has slipped by unnoticed.

V. THE MANUFACTURER AND THE SST

One of the basic objectives of Boeing's safety program in the Supersonic Transport Branch is to ensure that our awareness of the entire system does not diminish or falter. Sometimes problems arise that no one organization can solve. An example is the possibility of a cosmic radiation problem at SST cruise altitudes. This is a new aspect of the airplane—natural environment interface. The determination of whether or not a problem exists and the scientific skills necessary to such a determination are somewhat foreign to the airplane industry. Last year, General McKee, the Federal Aviation Administrator, announced the appointment of ten of the top radiation biology experts in the United States to study radiation aspects of supersonic transport operation and report to him their findings. At some point in time, and certainly prior to FAA certification of the Concorde for United States operations, the decision should be made as to what radiation detection and warning devices, if any, are necessary. However, we at Boeing have been aware of and have studied the problem for some time and feel that we are prepared to respond to whatever decision is made.

The problem of aerodynamic heating at speeds as high as Mach 2.7 is a problem that belongs more or less exclusively to the airplane designer and builder. The use of titanium to solve this problem brings about more

problems because of the relative newness of titanium as airplane structural material. In a sense, however, these are not really safety problems. They are better defined simply as technological problems whose successful solution is a prerequisite of supersonic transport operations. They are safety problems only in the sense that they will be subjected to safety review and analysis in the same manner as all other elements of the airplane's design. The proof-of-the-pudding insofar as the success of the advances in technology is concerned will lie in the flight tests of the prototype airplanes and the eventual certification by the FAA.

There are two impressive attributes of the SST that, at first glance, might appear to offer major safety problems. These attributes are those of size and speed. The SST is indeed a large airplane. Its length is a few feet more than that of a football field. However, close examination of the implications of size reveals no particular safety problems attributable to size per se. There is, of course, the fact that a single major accident will involve more people. However, size by itself does not necessarily produce new safety problems; in fact, increased size permits some safety improvements.

The large size permits a four-post main landing gear system which, in turn, permits a safe landing with one gear down on each side of the aircraft. The larger size means heavier construction which, in turn, provides greater passenger protection in survivable crashes of comparable magnitude. Finally, it can be logically argued that, in terms of the overall air transportation system, carrying more passengers in an individual aircraft results in fewer aircraft in the air for the same volume of passenger traffic; this, of course, tends to reduce the traffic problem and thereby increase safety.

With respect to the increase of speed, we should first note that speeds at low altitudes in high density terminal traffic and in landing approaches have not been significantly increased. Secondly, supersonic speed at high altitudes does not offer a significant safety problem once the technology has provided the solution to such problems as the aerodynamic heating I mentioned earlier. Our safety assessment is that these problems have been solved.

I believe at this point I should discuss the philosophy of Boeing's approach to safety and the content and structure of the SST Safety Program. The basic philosophy centers around two points which I can best express by stating two well-known and timeworn expressions: "Safety is everybody's business" and "Safety is a function of command."

Over the years, Boeing engineers at the lowest subsystem level have been imbued with the fact that they must design for safety. They must know the safety implications of every aspect of the design they are working on. The design manuals and procedural manuals which are their working tools spell out safety considerations, both explicitly and implicitly. The expression, "Safety is everybody's business," means that they must accept the responsibility to know these implications and considerations thoroughly and to act on them.

"Safety is a function of command" means that the responsibility to build a safe product belongs to those who are designing and building the product. This responsibility cannot be assumed by a group of safety engineers, for instance. The program director is responsible for the achievement of program objectives. He is thus responsible for the achievement of safety as the primary design consideration. When he delegates responsibility for the major parts of his program, as he must, the responsibility for achieving safety is inherent in such delegation.

A natural question now arises. If safety is a function of command and if safety is inherent in everybody's job, why should one need a safety organization? To answer this question, I would like to quote some statistics. Very few talks on safety are given without reference to statistics. I will not disappoint you. At the same time, I will not overburden you.

No matter whether you use as a base the number of hours flown or the number of passenger miles, the record shows clearly that commercial aviation safety has steadily improved over the years. This improvement has continued despite the fact that today's airplanes are many times larger and many times faster than those of a generation ago. For example, in 1950 the world's scheduled airlines (exclusive of the Union of Soviet Socialist Republics and the People's Republic of China) flew 5 million hours. There were 27 fatal accidents. The number of hours flown per fatal accident was 185,000. In 1961, the number of hours flown was 8 million. There were 22 fatal accidents, and the number of hours flown per fatal accident was 373,000.

By 1961, the jet aircraft had entered the picture in significant numbers. Considering jets alone, in 1961 there were 9 fatal accidents out of 1.35 million hours flown, or over 150,000 hours flown per fatal accident. In 1965, still considering only jets, there were 5 fatal accidents out of 3.6 million hours, or 720,000 hours flown per fatal accident. In the past two years, this downward trend has, unfortunately, been temporarily stalled. However, the overall improvement since 1950 in terms of hours flown per fatal accident has been close to fourfold.

However, despite this clear improvement, another fact stands out. This fact is the size of the aircraft, which I have already mentioned. We now have to work harder to keep the record good, because a single accident can be so serious. We must improve on the rate of improvement. This search for perfection becomes an increasingly challenging task as the goal draws closer and is *reason number one* for the increased attention in safety.

The economic motivation behind this reason for increased emphasis on safety is also clear. It is highlighted by the fact that the cost of product liability insurance is rising. I do not intend to discuss the various factors that have created this trend. Even without this trend, it is very clear, as I have stated earlier, that it costs money to have accidents. Additional emphasis on safety, throughout the system, can be more cost-effective than additional insurance premiums.

The second reason for the establishment of a safety organization stems

from the increased complexity of the airplane and of the system. The designers of the individual subsystems and sub-subsystems are still the best and most knowledgeable safety experts with respect to their own responsibilities. However, management needs a focal point to assist it in assessing and reviewing its overall safety effort on a system basis, to look for loopholes or lack of effective interface in the synthesis of overall safety, and to assist in the communication with all the other elements of the air transportation system, as well as those previously mentioned agencies that contribute to the safety of the system, such as the FAA, ALPA, and the Flight Safety Foundation.

Mr. William Allen, President of The Boeing Company, requires all of his operating divisions to establish such a focal point and to support it with the necessary and appropriate safety engineering staffs. Mr. Fred Maxam, Director of Engineering for the Supersonic Transport Branch, has stated in a communication to his design engineers that:

In recognition of the fact that we face a difficult task in the improvement of an already commendable record, a System Safety Program has been established within the SST Branch. The safety engineers involved in this functional activity cannot do your job for you. However, they can assist, remind, probe, offer constructive criticism, and analyze the interaction and compatibility of subsystems, and, finally, evaluate the total system.

The system safety program in the SST Branch, thus, involves the three following basic functions: design support, analysis, and audit.

The design support function involves the safety engineers and human factors engineers, who, on a daily basis, assist, remind, probe, and offer constructive criticism. Relying on the resources of our data center, they study past experience to arrive at judgments and recommendations. They participate in all design reviews and evaluations.

The analysis function is performed by safety engineering analysts, who employ the Fault Tree technique. This is a systematic, mathematically-based analysis of the interrelated sequence of events that could lead to a serious degradation of safety. This analysis permits evaluation of the adequacy of the redundant features, dual paths, and systems safeguards which are intended to eliminate the risk of a single failure's being able to produce a potentially unsafe condition. The Fault Tree technique was first developed in the Bell Telephone Laboratories in 1962. It has been successfully applied to the safety analysis of the Minuteman system. I do not have the time to explain the system in detail; I will point out that the University of Washington periodically conducts intensive short courses in this technique and its applications.

The audit function is performed through evaluation of the whole system and a synthesis of the findings of the design support and analysis activities. It includes formal milestones, such as the formal engineering safety inspection and the final operational safety analysis.

The safety program does not end with the completion of the design and the building and flight testing of the prototype. Training manuals, flight manuals, and maintenance manuals are reviewed from a safety point

of view. The quality assurance and control programs are key elements of the overall safety program. The safety and quality assurance programs of the subcontractors are reviewed and audited. Finally, and very importantly, close communications, including joint reviews and evaluations, are maintained with the airlines throughout.

VI. CONCLUSION

There are always some people who view tomorrow with alarm. Indeed, there are some people who view today with alarm. With respect to whether one should view today's safety record with alarm or not, I merely point to a hard-headed segment of our society — the insurance companies. As the president of the Air Transport Association of America has pointed out, "Insurance companies, many of which refused to sell life insurance to pilots before 1937, now consider an airline pilot's work just as safe as that of, for instance, a grocery clerk. Both pay the standard premiums. Among those who are charged extra premiums are dock workers, lumberjacks, bartenders, and jockeys."

General Maxwell of the FAA has said that the SST will be the safest airplane ever introduced into airline service. Boeing intends to do its share in achieving this goal.