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GENERAL AVIATION AIRCRAFT SAFETY, THE  
PRINCETON UNIVERSITY CONFERENCE (119TH)  
HELD AT PRINCETON, NEW JERSEY ON  
OCTOBER 24-25, 1973

Princeton University

Prepared for:

Federal Aviation Administration

October 1974

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| 16. Abstract<br><br><p>The Federal Aviation Administration and Princeton University co-sponsored a two-day General Aviation Aircraft Safety Conference at Princeton University in Princeton, New Jersey October 24-25, 1973. The conference was organized to examine the accident record of general aviation aircraft, and to explore possible approaches to its improvement. Current research and development efforts in the areas of airworthiness and crashworthiness were discussed along with the cost and regulatory implications of increased safety. An integral part of the conference was the continuous display and demonstration of aircraft used for lightplane research. This display was located at the airport on the James Forrestal Campus.</p> <p>This document, which is a record of the conference, includes presentations by those working to enhance general aviation safety--Government, several universities, aviation insurance companies, and the aircraft manufacturers.</p> <p>Approximately 150 persons attended representing most segments of the U.S. General Aviation community.</p> <p style="text-align: center;">Reproduced by<br/>NATIONAL TECHNICAL<br/>INFORMATION SERVICE<br/>U S Department of Commerce<br/>Springfield VA 22151</p> |  |  |
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## FOREWORD

During the past few decades, improvements in performance and utility have fostered a steady growth in the use of light airplanes for business and pleasure flying. The accident record for this means of transportation remains poor, however, compared to that for the scheduled air carriers or for various ground modes. The purpose of this conference is to examine the scope of this problem and to explore possible approaches to its solution, particularly with regard to application of advanced aeronautical technology. Current research and development efforts in the areas of airworthiness and crashworthiness will be discussed, as will the costs and regulatory applications of increased safety; special research lightplanes will be displayed and demonstrated. The conference should provide a clearer picture of future lightplane R&D requirements, and of the respective roles of industry, Government, and the research community in achieving increased aviation safety.



## PROGRAM

October 24-25, 1973  
Woodrow Wilson School, Princeton University  
Princeton, New Jersey

### WELCOMING REMARKS:

Courtland D. Perkins, Chairman, Dept. of Aerospace & Mechanical Sciences, Princeton University

Gustav E. Lundquist, Associate Administrator for Engineering & Development, Federal Aviation Administration

Spencer S. Hunn, Director, Systems Research & Development Service, Federal Aviation Administration

### SESSION I - THE GENERAL AVIATION ACCIDENT RECORD

Chairman: Richard Collins, Senior Editor, Flying Magazine

"Analysis of General Aviation Accident Records"

Charles O. Miller, Director, Bureau of Aviation Safety, National Transportation Safety Board

"General Aviation Accident Patterns"

Donald E. Kemp, Chief, Accident Investigation Staff, Flight Standards Service, Federal Aviation Administration

"The Accident Record in Terms of the Pilot"

Jack J. Eggspuhler, Director, Department of Aviation, Ohio State University

Discussion - in addition to the above named speakers:

Jerry Shrout, Vice President, Claims, AVEMCO Insurance Company

Paul Alexander, National Transportation Safety Board

### SESSION II - GENERAL AVIATION DESIGN AND SAFETY R&D OVERVIEWS

Chairman: Edward Seckel, Professor, Department of Aerospace and Mechanical Sciences, Princeton University

"Crash Survivability"

P. Frank Castellon, Manager, Crash Survivability Program, Federal Aviation Administration

"General Aviation Handling Qualities Research"

David R. Ellis, Manager, Flight Dynamics Research, Department of Aerospace and Mechanical Sciences, Princeton University

**"Design Considerations for Stall Avoidance"**

Seth B. Anderson, Assistant for Interagency Programs, NASA-Ames Research Center

Discussion - in addition to the above named speakers:

Robert P. Harper, Deputy Head, Flight Research Department, Calspan Corporation

Karl H. Bergey, Professor, Department of Aerospace, Mechanical, and Nuclear Engineering, University of Oklahoma

**SESSION III - REGULATORY TRENDS**

Chairman: Archie Trammell, Editor, Business and Commercial Aviation Magazine

**"Airworthiness Certification and Flight Safety Regulation"**

Dennis Tuck, Chief, Flight Test Branch, Flight Standards Service, Federal Aviation Administration

**"Environmental Factors"**

Edmund W. Sellman, Office of Environmental Quality, Federal Aviation Administration

**"Economics - General Aviation Cost Factors"**

Gene S. Mercer, Chief, General Aviation Branch, Office of Aviation Economics, Federal Aviation Administration

Discussion - in addition to the above named speakers:

George D. Kittredge, Sr., Senior Technical Advisor, Environmental Protection Agency

**SESSION IV - PROSPECTS FOR AN IMPROVED SAFETY RECORD**

Chairman: John L. Baker, Assistant Administrator for General Aviation, Federal Aviation Administration

**"Manufacturers' Overview"**

Edward W. Stimpson, President, General Aviation Manufacturers Association (GAMA)

Discussion - in addition to the above named speakers:

John Brennan, Executive Vice President, U. S. Aviation Underwriters, Inc.

Lawrence P. Greene, Assistant for Aeronautical R&D, Office of the Secretary, Department of Transportation

Jack R. Hunt, President, Embry-Riddle Aeronautical University

Roger Winblade, Manager, General Aviation Technical Office, NASA Headquarters

**APPENDIX I - LIST OF ATTENDEES**

## Welcoming Remarks

Courtland D. Perkins  
Chairman, Department of Aerospace and Mechanical Sciences  
Princeton University

The Princeton University Conference has become a very important part of the life of Princeton, and we try to focus these conferences on very important problems of the day and certainly the ones we are dealing with in this session is one of those. I want to say that those of us who look at these very difficult problems like aviation safety from the vantage point of the university and from the engineering side have one very major concern about the way things are going, and that is that it is very difficult to attract our bright young engineers or students to the field of the real world such as general aviation safety.

In point of fact, we had a meeting of the A.I.A.A. here some weeks ago in which it was identified by Pratt and Whitney, Boeing, Lockheed, and what-not that the youngest man in their technical staffs today happened to be about twenty-nine years old. This seems to me to be a tremendous problem to the country, because if we are going to get innovative thinking, innovative thinking comes from people between the ages of twenty and thirty. That is where innovation comes from. Evolutionary progress comes from the older types like ourselves. One of the great problems, therefore, I think, is how are we going to get innovative thinking back into this country, and certainly this problem that you are dealing with needs innovative thinking, and there are very, very few students in the engineering schools who (a) are interested in any hardware type problems, and (b) in the whole general field that is addressed by this conference.

So I hope you might think about that or keep that in mind. If you have any suggestions for the universities, I would be delighted to hear them. But we certainly need motivation. We need to motivate bright young people back into these sorts of fields. Thank you.

Gustav E. Lundquist  
Associate Administrator for Engineering and Development  
Federal Aviation Administration

I would like to add my welcome to that of Professor Perkins. We in the Federal Aviation Administration are very much concerned, as you know, with the subject of general aviation safety. The Administrator, Alexander Butterfield, has an early meeting with his top staff every day and we review not only the operation of the system the day before, but also the accidents that occurred during the day before. And I am always appalled, especially after a long weekend or holiday period, especially when the weather has been sort of sour, at the number of reported general aviation accidents. As you know, the primary cause in many of these accidents is pilot error, and as a pilot, I take exception to that overall blanket cause factor. There are always many contributing factors to that pilot error. You can talk about the handling characteristics, the stability, the cockpit layout, the accessibility of controls, etc. that perhaps led that

pilot to make that mistake. And this, I believe, is where the user groups, industry and the Government can do a great deal.

We in the FAA have had a very aggressive general aviation accident prevention program. This program has been aimed primarily at improving the qualifications and skills of pilots. We also have a very aggressive research and development program to work on the certification criteria for general aviation aircraft to make them safer, to make them handle better, to make them more crash survivable, better restraint systems, so that in case of an accident that we can keep the injuries to a minimum in so far as the crew and passengers are concerned.

I know that you will enjoy the display and demonstration of the research general aviation aircraft at the Forrestal Airport. These sorts of aircraft are the ones that will provide the technology that can be applied to future general aviation aircraft and make them safer. I know this will be a very successful conference. I think we all have a common goal and that is to improve general aviation safety. Thank you.

Spencer S. Hunn  
Director, Systems Research and Development Service  
Federal Aviation Administration

I am not like Gus Lundquist. I never won any races, but I did sign a tab for \$300,000 for wrecking a B-24 one time.

The FAA is very pleased to join with the Princeton University in sponsoring this conference today to investigate ways and means of improving the design characteristics of light and general aviation aircraft. Over the years, we have not spent a lot of time doing this. We really have not had a program that was aimed directly at research and development toward increased safety. The FAA has had programs aimed at improving the safety of general aviation airplanes, but these programs had more to do with education, pilot training, in-flight operations, and things of this sort. And they were successful. They were successful to the point where there has been a reduction in the number of accidents that have taken place in the past years. But they have not been successful to the point where we have eliminated accidents to the degree that we think they could be.

The objective of this symposium, as I see it, is to assemble you folks who are responsible leaders in aviation to give us your thoughts on ways and means that we can come up with programs that will do the things that we are trying to do. What we want to do today during the course of this symposium is to review for you some of the research and development programs that we have and get your comments on those research and development programs. We would like to have you review some of the accident statistics to see if there are ways and means that they can be (I do not want to say improved) reduced. We also would like to have your ideas on what kinds of research programs we might enter into in general aviation and light aircraft that might work toward reducing the accident rate.

These are the kinds of goals that we would like to set up for this symposium. We feel that it can be successful if those of you who are assembled here participate actively in it. I know there are a lot of

subjects that are on all of our minds; the user cost, the changes in pilot proficiency requirements, the changes that we have instituted for instructors and their proficiencies. We would like to avoid these during this symposium and dwell on the research and development aspects that we are going to outline.

This symposium is really a direct outgrowth of a program that we have had with Princeton University, which was to investigate design and handling characteristics of light airplanes. It has been rather successful, so much so that we are going to extend the contract to carry it a little bit further. Out of this, we would like to see improved designs for light airplanes so that we might come up with criteria that would make it possible to establish better regulatory goals. These things we are all going to strive for. We hope that they will be accomplished.

In the past, we have really depended more on the fallout from other programs in so far as the application of design to light aircraft. I think the entry of the FAA into research and development programs for design characteristics is somewhat new and it is one that could be pursued even more vigorously than we have in the past. All of the actions that have been taken in the past have gone toward improving the safety record, but it is not good yet. You know it is ten times safer to ride in automobiles than it is to fly in some of the general aviation airplanes, according to statistics. It is an order of magnitude safer to fly in scheduled airlines than it is to fly in general aviation airplanes. Therefore, we have a goal to raise the safety level to a point where it is comparable at least to these other two modes of travel.

These are the kinds of things that we want to get out of this symposium, the ideas, the programs that will enable us to design aircraft that are safer, that have better handling qualities so that they might be safer, and to give us a capability, if there is a crash, to increase the probability that there will be survivors in that crash. This is what we want to get out and we feel that it can be achieved if those of you who are assembled here today will participate freely, give us the benefit of your ideas and your thoughts.

I think with those statements, I will turn it back to Ed because I think these really are the goals that we would like to achieve. Thank you.

SESSION I - The General Aviation Accident Record

Chairman, Richard Collins

Senior Editor, Flying Magazine

## Analysis of General Aviation Accident Records

Charles O. Miller  
Director, Bureau of Aviation Safety  
National Transportation Safety Board

The title of my paper today, "An Analysis of General Aviation Accident Records," is not really what I want to talk about, for, among other things, I have already done this in a paper I gave at the S.A.E. meeting two years ago. It had almost the same title and, quite frankly, things have not changed. In fact, I was searching for a better title right up to the very last minute while we were chatting outside the door here and I really did not have one. However, Jerry Shrout here told me of an incident, a true case he had at home, and had I known it ahead of time, I can assure you that would have been the title of the paper.

As Jerry tells it, he had an argument with his wife about something and he was apparently getting the upper hand when finally, in disgust, she shouted at him, "What else do you have besides facts to back up your positions?" That describes perfectly, why I am here this morning, whether you know it or not and hopefully I will convey this before we are finished.

I will try to supply some data. The printed paper contains additional data that will be available in the proceedings, but, I reiterate, I do not really think things have changed too much in the last several years, and most of you, if not all of you, have heard this time and time again. I do have handy-dandy bits and pieces of information here so that we can get the questions out in the open. However, in view of our distinguished Chairman's past interests, I will tell you now that when we compare single and multi-engine aircraft, only one in eight accidents are multi-engine but one in five of the fatal accidents are multi-engine.

I would really like to talk a bit first about the process of gaining these accident records, and talk specifically to their limitations as we see them at the Board and how you all may want to use data of the type that we generate. I think it becomes particularly important to understand the process of gaining these data and their limitations if you are trying to set up priorities for what you want to do.

I am tempted to review some of the detailed accident report forms because, believe it or not, a lot of people do not understand these. However, we are including them in the printed text. Also I am not going to get into detail of cause factor analysis except maybe in one or two places because I think that most of you have seen this before. Anything I would say today might be redundant. Again, I do have the data here if we want to use it.

Let us first then explore the investigative task as we see it in civil aviation, particularly with an emphasis on general aviation. We are talking, first of all, about 4,500 accidents per year, give or take a couple of hundreds. Of these 4,500 accidents, we are talking about 700 or so fatal accidents. If we want to go back ten years, the total number of accidents is actually 5% less than it was ten years ago. The fatal accidents are almost 50% more. What does this tell us? It begins to tell us something about the nature of the investigations that have to be conducted. They are far more complex now than

they used to be. Just by definition, the severity of the accident, that is, the loss of more people, and more destruction of the machine makes the investigative task more severe.

Above all, the sophisticated systems by comparison to say, those of ten years ago makes the accident investigation task considerably more complex now. Beyond that, we have a lot of outside people who are involved in investigating accidents. Within the safety board on the aviation side, we have some 130 technical people and another 40 administrative type. The number of technical people give or take one, is the same number we had eleven years ago. So our investigative task has been an interesting one, trying to keep up with the advances in aviation with exactly the same number of people to do actually a broader job.

Only 50 of the 130 technical people we have are out in the field where the bulk of the general aviation investigation is performed. It is obvious that we could not do the job alone and we certainly do not try. The FAA has been delegated all of the non-fatal accidents involving rotorcraft, aerial application, amateur-built aircraft, restricted category aircraft and all non-fatal accidents involving fixed-wing aircraft which have a certificated maximum gross weight of less than 12,500 pounds that are not involved in air taxi operations. The Board investigates directly all other fatal aircraft accidents and those non-fatal accidents in such areas as air carrier, mid-air collision, air taxi operations, etc. What this means is that the safety board handles from beginning to end about 18% of all civil aviation accident cases.

The FAA handles only the field fact-finding phase of something like 82% of the accidents; however, the one thing the Board does do in every case is analyze it and make a probable cause determination. I think it is obvious that the FAA has a major role in the determination of the facts at the scene of the accident. Actually (I guess Don Kemp, FAA, could correct me on this) their personnel assigned to this job only equate to about 65 or 70 man-years, so this is not many people either. Also, they have to share their support of us in accident investigation with many, many other duties that they have so we could not do it all with just the NTSB and the FAA.

Because of this, we depend to a very large extent on the owners and operators, particularly in those cases where the damage is not severe. It has been variously estimated (and we have actually measured this on occasion) that perhaps half of those cases that the FAA does "the field fact-finding investigation" for us are really derived from supplemented owner-operator reports and not by total field investigation work performed by trained specialists.

Then, of course, we have the parties to the investigation: the insurance firms, relatives, friends, manufacturers, whomever it might be. I can assure you that this cooperation and assistance, although it is sometimes maligned as being prejudicial, has on the contrary, I think provided overwhelming support to us in our investigations, and has been very much on the positive side. Without this assistance, I can assure you, we would not have an effective civil aviation accident investigation program.

As you have seen, a lot of people have a piece of the action and in case you have not gathered it by now, what I am trying to give you, is some of the



background information to qualify, if you will, the information that you may see come out at a later point as data runs, accident reports, or what have you. It is a very involved business.

Let us examine, quickly, the phases of this whole data collection process. For example, the field fact-finding, that is, getting out to the smoking hole and seeing what it tells us, is just a piece of the action. The investigator, to be sure, puts together a factual report and the factual report rests ultimately in a file, a docket, in Washington. That, of course, is available to the public. If anyone would like to drop in and see it or write for it, they can get access to it. Then we have the NTSB investigator's analysis of the situation and I reiterate it is our job to analyze and determine cause on all accidents. This is not a part of the public record, but it is in a file in any case.

Next, there is the determination of cause. In other words, we have the facts, we have the analysis, but what does this mean in terms of cause factors? That has to be done and of course ultimately when this becomes subjected to Board approval, it becomes a part of the public record. But that still is not the whole package. We have a coding process to go through. For four or five thousand accidents a year, it is obvious that we have to go into a fairly extensive data classification system. The use of such an extensive system as this, has its own problems too. I will discuss it a little bit more later.

Finally, of course, we have computer printouts of these data. We can get them in brief format which comes out four or five times a year on all accidents, or we can make any of a number of analytical type runs that we wish for whatever purpose we like. One thing, I have reasons to believe people do not appreciate, is that we try what we call a parallel quality assurance program within the Bureau to assure some degree of objectivity, indeed, a high degree of objectivity. When an investigator and perhaps his field chief go through a case and it comes back to Washington for analysis and coding, we have people look at this report quite independently.

They will look at the factual report, do their own analysis and their own conclusions and then and only then compare it with what had been submitted to begin with. If these two independent looks by qualified people coincide, so be it. If they do not, then we have ways of trying to resolve the differences, with the idea being, of course, to try to provide the most objective findings and objective cause determinations that man can reasonably do.

Let us be more specific, then, in terms of data limitations. The first one always starts right at the scene of the accident. Any of us who have been out tromping in the wilds and looking at the smoking holes will, I think, agree that the terrain, the weather, the condition of the wreckage and how much time we might have available are things that can, and in fact do, affect the accuracy of the information we get, and that in itself is the biggest single limitation. If we do not get it from the accident scene or its associated studies, we are just not going to have it in any record. It is that simple. And so much of this information does not last if we do not get it right away. It is either physically lost, destroyed or emotionally forgotten. I cannot stress this too strongly. The validity of the information that ultimately comes out in reports is first and foremost a function of what we gain at the scene of the accident and immediate environs thereof.

In terms of getting back to the time spent investigating, I can assure you that both we and the FAA are spread awfully, awfully thin today in trying to cover all accidents in the depth that we think they ought to be covered.

The second big limitation I would like to speak to here is you might say the data recording system. Confusion has occurred following some of our special studies where people do not understand the difference between two types of accidents. A very simple example of this is if we have an engine failure and the aircraft lands gear up, we might get two entirely different stories or understandings of what is going on if we just happen to see an accident summary that listed this as a gear-up accident. So there are little things like this that we have to appreciate.

Far and away, the biggest limitation for the use of the data from an analytical point of view has to do with an item called probable cause. Let me quote you two definitions from our Analyst' Handbook; - one of probable cause and the other of so-called factors. "Probable cause(s): Conditions and/or events, or the collective sequence of conditions and/or events, that most probably caused the accident to occur. Had the conditions or events been prevented or had one or more conditions or events been omitted from the sequence, the accident would not have occurred." I do not think that it took more than about twenty years to figure out how to put those words down.

"Factors: Related conditions or events which existed or occurred coincident with the conditions or events that most probably caused an accident which may or may not have contributed significantly to the accident. The omission of factors from the occurrence would not necessarily have prevented the accident." If you are not thoroughly confused by now, think how we are when we try to work with this day in and day out, and we still have our problems with it.

But let me simplify it to this extent. The Board feels, as a matter of policy, clearly and distinctly that there is rarely a single cause or a single factor which gets into the accident sequence. We are charged by law to determine probable cause of every accident. It has been extremely difficult to come up with a definition of the words of the type I just mentioned that meets the tests of all people. It is interesting to me that within the past month, the U.S. Air Force has eliminated the determination of primary cause from their accident investigation procedures. It is also interesting that next year in Montreal, we fully expect to see this question raised internationally as to whether or not we should even worry about determining a probable cause. I can assure you that this has been a subject of much discussion at the Board. But the point here is, we have to be careful when somebody says, "I found a little nugget and if you correct this, this accident would have been prevented," because as we will see a little bit more by example, this is an over-simplification.

The other point on this data recording system that I would like to speak to, is this business of the logic of it. Our data coding methods have been tentatively adopted as an ICAO standard; it is already in use by several foreign countries. So, I think it can be argued that it is probably as good as anybody has. On the other hand, one gets continually perplexed when he finds that say production design factors are listed under personnel.

Well, so be it. One of the more profound things I will tell you today, is that one logic in this business is good as another as long as it is logical.

Seriously, what I am trying to say here is that to understand accident data, it is absolutely vital to know the system that is used to gather, store and manipulate it. If you do not have a detailed knowledge of that, I submit to you, you are going to misuse the information. Many of the arguments that we have had about studies and findings that the Board has put out have been mainly because people do not (and I might add our own people as well as others) fully understand how this data system is put together.

Again, let me speak to something specific that I think would be of interest to this group. Let us take this item of poor or inadequate design. It can be shown that in 1971, only 22 out of 4,567 accidents were coded or attributed, if you will, to poor or inadequate design. However, it also can be shown by studying the problem that this category is seldom if ever used to categorize a basic design problem. The only time we really use this term, per the ground rules that are set up, is when the part of an installation clearly fails to meet applicable minimum design standards, as may be reflected in the FARs or S.A.E. standards, or manufacturers' standards, or others that are rather well known.

Why don't these things represent, you might say, a bigger part of the accident prevention potential in design? First of all, it is not easy to identify technically, or prove design deficiencies in the investigation analysis, particularly when considering a single accident compared to a group that is available to study. The field investigator or the analyst has a difficult time trying to go back in time to find out who did what to whom at the time of design. It is a very difficult task just in the mechanics of it.

Secondly, there is no single set of criteria against which the design can be measured. That is what the courts are for. The courts spend lots of money trying to figure out what is the standard to which a given case should be measured. I think it would be obviously unfair to ask our investigators or analysts to try to do this and be all-seeing experts in this area wherein the courts will literally spend months and years attempting it. I think the biggest thing that causes difficulty in trying to really pin down design factors in accidents, is the fact that design standards in the broad sense change with time. Hence, confusion can occur because a design deficiency today may not have been a design deficiency when the aircraft was originally developed. For these reasons, extreme conservatism has been used by our analysts in coding an accident "poor inadequate design." It would be incorrect to assume that the Board does not believe design deficiency may have been involved in significant numbers of cases just because an apparent low number appear in the computerized printout.

Further, it can be shown that based on special studies, that is, detailed analysis of individual cases in groups, design deficiencies have been found to exist when they do not actually appear in the accident case or computer files per se. Examples of this are the design-induced pilot error study, the stall-spin study, the engine failure study and others like them. The special studies, in fact, are what we really need to get this type of a picture.

Speaking of pictures, let me project the one slide that I brought with me here today. What you are seeing here is a rank order of causes by percentage. In other words, the classic pilot, personnel, weather, power plant, etc. If we want numbers and we want to compare them over the last three complete years for which we have data analyzed, this is what we see. As usual and as spoken to before this morning, the term "pilot factor" is always there. Now is this because he is just the guy on the end of the chain? Is it because we are all experts in human behavior, therefore we can assess what he does good or bad from our personal standards? Or is it because we do not get into the depth of investigation of human factors as much as we would like to? We may comment on that more. Frankly, when I see a chart like this, and you will notice that the hit parade does not change that much from year to year. I think of it in terms of involvement; that these things are involved. It does not mean that the only way to correct No. 1 on the hit parade is to try to work on the pilot. We may well want to hit that hard, but we may find the only way we are going to reduce that so-called pilot factor is to do something in the other areas, not necessarily those listed here.

We can find, in the printed paper, very detailed breakouts of each and every one of these categories. The detailed breakouts give us information from which intelligent people can make intelligent decisions but only when supplemented with information from other sources.

I would like to close my remarks here with something that goes back to the S.A.E. paper I mentioned earlier. It gets to this business of why are we in this general aviation safety business at all? Why are we really here at a meeting of this type? When we come right down to it, I am sorry to say, general aviation just is not killing enough people. We are only killing 1400 or 1500 a year. They do that at railroad crossings and in recreational boating. That is nothing compared with 55,000 or 56,000 a year on the highways. What are we worried about?

As strictly personal observation, I like to look beyond the moral and economic aspects. I like to project back in time to when we were only killing 1400 people or so on the highways. This was just shortly before 1910 and I submit to you that if the highway people in those days had had the kind of accident prevention knowledge that we have today in aviation and had translated it to automobiles at that time, they would never have reached 55,000 to 56,000 deaths a year on the highway. If there is one thing I have learned in this business I am in now, it is that the public is a strange breed. They will accept, if I may use that term carefully, a lot of injury and a lot of death, if it comes as a kind of evolutionary process. Therefore, I submit to you, the reason we are working in general aviation safety is so that we never reach in aviation, the level of public acceptance, if you will, that we have seen on the highway.

# **RANK AND PERCENTAGE BY CAUSE OF ACCIDENT**

|                      | 1970 |            | 1971 |            | 1972 |            |
|----------------------|------|------------|------|------------|------|------------|
|                      | RANK | PERCENTAGE | RANK | PERCENTAGE | RANK | PERCENTAGE |
| <b>PILOT</b>         | 1    | 84.52      | 1    | 88.66      | 1    | 82.13      |
| <b>UNDETERMINED</b>  | 2    | 10.48      | 6    | 4.35       | 2    | 9.01       |
| <b>PERSONNEL</b>     | 3    | 8.23       | 2    | 9.16       | 3    | 6.94       |
| <b>WEATHER</b>       | 4    | 7.74       | 5    | 4.97       | 5    | 4.73       |
| <b>POWER PLANT</b>   | 5    | 6.94       | 3    | 6.06       | 4    | 6.35       |
| <b>TERRAIN</b>       | 6    | 4.84       | 4    | 5.28       | 7    | 2.51       |
| <b>AIRFRAME</b>      | 7    | 2.74       | 7    | 2.64       | 8    | 1.03       |
| <b>MISCELLANEOUS</b> | 8    | 2.58       | 8    | 1.55       | 6    | 3.84       |

## General Aviation Accident Patterns

Donald E. Kemp  
Chief, Accident Investigation Staff  
Flight Standards Service  
Federal Aviation Administration

In examining our action pattern again, really, the only pattern that I can see is one of a lack of exposure on the part of our aircraft designers. Our aircraft designer is, I think functionally oriented but not truly trained in the human factors design for the pilot. We all recognize the value of some sort of standardization, but if you look at six different aircraft, you will find at least six different cockpit layouts. Our Federal Air Regulations allow this, and of course they should if aircraft design is to progress. However, there should be some standardization to reduce the number of the design-induced accidents. We have done this to a large extent in our air-carrier aircraft.

Aviation safety and accident prevention are for practical considerations one and the same which naturally brings to mind certain well-known approaches to the problem. First, we have the efforts being made in accident prevention through the education and training of our pilots, the general aviation accident prevention program that the FAA currently has in being.

Second, and not as well advertised, is the hardware or the mechanical consideration which includes the design, fabrication, arrangement of our cockpit controls, aerodynamic improvements, etc.

The education and training of the pilot are extremely important and he is the main consideration when aviation safety is thought of and every reasonable effort should be made to encourage the upgrading of his knowledge, skills, and ability.

In the second consideration, the design and fabrication of the aircraft must be brought in for its rightful share in this total consideration of aviation safety. This is not as simple as it may sound. A factor not considered often enough is the medical aspect and I am not referring to the regulatory medical standards which the pilot has to meet. Instead, I am referring to the human injury or survivability factor. To be most effective, the engineer needs the data to be incorporated into the design rather than attempting to fit it in after the basic design has been decided on. To do this, our engineer needs many facts from the medical people about the human body; how much force it will withstand, how long, etc. without becoming a fatal statistic. I have no doubt that the modern know-how could encase the pilot and the passengers in a capsule if we could make it injury proof, but of course, it would not be able to fly. It would be too heavy.

How about the costs? At some point, the aircraft designer must decide how the greatest protection can be given to the occupants while at the same time giving due consideration to other aspects of cost, flying qualities, maintainability, etc. In the early years of our aviation, very little attention was given to safety, especially to protection of the occupants. Our greatest effort was to make a machine that would fly. It was fortunate through our trial and error that the tractor type of power plant was the arrangement that was found to be the most efficient rather than the pusher

type. Many pilots have lived through crashes due to the energy absorption capability of the engine mounted ahead.

During the period between World War I and World II, almost no deliberate engineering consideration was given to crashworthiness as a safety factor in our aircraft design, even less from the medical standpoint. Early in World War II, the study of human survival in other than aviation crashes showed the tremendous capacity of the human body to absorb crash load forces if reasonably protected and impact forces were evenly distributed. In pursuit of what we call crashworthiness and survivability, the aeronautical engineer adopted the principles used in designing packaging for the shipment of various cargoes. First, the package should not open up nor collapse under expected conditions of force. Second, the structure shielding the inner container must be made of a brittle, but not too brittle or frail materials but rather should resist forces by yielding (energy absorption again). And third, the article should be packaged to be held immobilized.

It is the last principle that I think brought the aircraft designer to the placement of the seat belts and shoulder harness in the aircraft.

As might be expected, the most frequent type of serious injury in the survival accidents are the fractures of the skull, lesions of the brain, the crushing of other facial bones, and injuries of the head. It is not easy to fully appreciate that the head weighs as much as a ten pound sledge hammer, and when it strikes an object at speeds in excess of 40, 50, 60 miles an hour and the object will not dent or yield, then the head itself must do the yielding. Although the seat or the shoulder belts do not check the velocity of the head, their safety contribution is that of limiting range of movement.

The design features of many modern aircraft have seat backs of ductile material covered with the proper padding which provides protection to the passenger if he is suddenly thrown forward. The progressive collapse of structure is designed to be less than that which would be otherwise a lethal blow. One of our first aircraft to incorporate this type of design was the Convair 240. The instrument panel had long been a culprit as a cause of head injuries, and this prompted several design changes such as the padding of instrument panels, recessed or removable knobs to reduce the injury potential.

A good example of how impact forces are absorbed is the use of the helmet, which is now used, I think, by all of our agricultural operators. This is able to absorb a tremendous amount of energy that is generated in a crash.

As an example of head injuries that could have been avoided was a record of a well-known light aircraft where a sudden stop almost assured that the person in the rear seat would receive head injuries by striking the tube that formed the back of the front seat.

No one expects that these improvements will assure safety for the occupants when the aircraft is flown into a mountain at cruise speeds of more than 100 miles an hour. However, our continued research and application of engineering principles in conjunction with our medical history should determine the survival levels and do much to increase the number of survivable accidents. We must remember that not all of the fault for the slow progress in the protection of our pilots and passengers rests with the engineer. The occupant is the one most often having the greatest reluctance to use the provided safety measures. Many accidents we find, where the shoulder harness has been

installed, but was not used. The opinion of some of our medical people in these accidents is that this pilot could have survived had he worn the shoulder harness.

Chuck has already mentioned that part of the lack of information is attributed to the method of categorizing causes of accidents in terms of pilot or material or personnel failures.

Early in the search for information on how much force a human body can stand, the medical people extended their efforts beyond the aviation industry, and one of the early surprises was a workman who survived a fall from the top of a 180 foot smokestack, landed on a pile of gravel face up, body flat and had one broken bone. There was a small depression in this gravel pile and he broke a small bone in the wrist. He was kept in the hospital twenty-four hours and released. There were no other injuries. In other accidents that have been studied, the authorities have computed that the body is able to withstand forces of 200 g's for a short period of duration.

Now I would like to turn our attention to another problem which needs attention urgently and, for want of a more descriptive title, we have called it design-induced pilot error. Probably, the only pilot who is not confronted with this problem is the one who has spent his entire career flying the same aircraft (I am assuming he is going to have his gear down and welded). When you stop and think of the accidents or near-accidents involved, the arrangement of such things as fuel systems, power controls, prop controls, electrical systems, landing gear, flap controls, similar controls that, because of location, depended upon identification by feel rather than by sight. You could go on and on with such a list because I know of no two airplanes where the arrangement is identical. I think we see this from year to year in the same model.

To illustrate some of the examples, there was a recent fatal accident. The pilot was competent and experienced in the aircraft. The aircraft was a well-known make that had been modified to incorporate some advanced design features. The unknown factor was the fuel system. There were two designs that were approved which were slightly different in operation. The pilot selected a tank for takeoff he believed to be full. This would have been correct in the aircraft he regularly flew, but unfortunately this fuel system arrangement was different and the result was a takeoff with a near empty tank. The engine stoppage at a critical point resulted in five fatalities.

Some other designs that contribute to accident count include fuel valve selector handles. Now I ask you, does the long or the short end of the handle indicate where the fuel tank selector is? Another design placed a fuel valve assembly in such a manner that it must be rotated ninety degrees from last year's version of the same make and model. In one of our light twins, an engine-out operation was sort of like Russian roulette, and when you have fuel but the selection of fuel valves, boost pumps, etc. has two sets of instructions, neither of which was exactly a complete explanation, needless to say, the pilot did not always select the right combination.

Another mid-year model change involved a fuel selector where a right or left rotation really meant nothing unless the control had first been depressed to engage the slot and then rotate the valve assembly to the correct selection. In one of the earlier designs, the manufacturer had placed the fuel on-off valve in the cabin adjacent to the rudder pedal. This resulted



in several accidents where the pilot inadvertently knocked it to the off position. I do not know if the corrective action was the best in the world, but they did safety wire it to the on position.

I think you are all familiar with the fact that many of our aircraft have fuel gauges where it is possible to select and read the quantity in a tank when you are not actually using fuel from that particular tank. I know that many of you are aware of the arrangement of props, throttles, mixture controls on one multi-engine aircraft, and in the next light twin you get into, the arrangement is reversed and sure enough when you think you are pulling props back, you might be pulling mixtures off and this has caused a lot of accidents.

One of our leading type of accidents that really keeps our maintenance shops working and our insurance companies busy giving out all this money they have, is our design of the landing gear warning horn. Our engineers are now getting into the human design aspects of the thing. They have put a horn in so if you pull the throttle back, you get the horn, but then you do not want to bother the pilot so you have to give him something to turn it off.

Fortunately, we have very few accidents that involve personal injuries--this is the standard wheels up landing. "I meant to lower, but that horn went off and I was too far out so I turned it off and then I forgot it."

Often we find the design is good but our instructions to the owner and operator are not as good. A well-known general aviation aircraft experienced quite a run of accidents beginning with loss of control at excessive air speeds and our investigators found there was one common factor in all of these events. Not one of the accidents had any indication of an attempt to lower the gear to increase the drag. Questioning of the non-professional pilots flying this aircraft revealed that not many of them were aware truly what the gear red line meant. The majority of people thought the gear red line mark on the air speed indicator was there to protect the gear and of course you and I know it is not. It is there to protect the gear doors and fairings. If this information had been made available to the non-professional pilot, I think we could have saved many lives in aircraft.

Too often our design of aircraft leads to complacency. In one area, the visual check for gear down should always be made, in my opinion, regardless of what warning indication you have, whether electronic or mechanical. One of our well-known light aircraft had at one time a red and green light in the instrument panel which was real good. When your gear was down, you got a green light; when your gear was up, you got a red light. The only problem was that all this did was to sense the position in which you placed the landing gear handle; however, it did not tell you the position of the gear.

I know that we could talk on and on about these types of occurrences, but I would like to close by reminding you that, regardless of our best efforts, the past shows that complacency, often of our own creation, has ruined much of the efforts toward an accident-free aviation industry. To verify this statement, one only has to remember the aircraft which incorporated many of the favorable design features including the spin-proof design. However, the record further shows that a gross oversell of this quality achieved an accident record of such magnitude that the insurance companies particularly would not even insure the aircraft any more.

I hope that during this session with the exchange of information, that we will be able to generate here that we can achieve better design and better information toward the deficiencies that we find in accident investigation, and I hope that we will get some good input for the FAA to take action on.

## The Accident Record in Terms of the Pilot

Jack J. Eggspuehler  
Chairman, Department of Aviation  
Ohio State University

Dr. Perkins made a statement earlier upon which I would like to comment thus departing from my presentation somewhat. One of the things he mentioned to you was the fact that we do need innovation when it comes to research. When it comes to getting some new ideas and some fresh ideas about aviation safety, we need help. It is not panning the intellect of our aviation industry. He is questioning where do we go from this point on, and he is so timely in raising that question.

In consideration of General Lundquist's remarks earlier, I would remind everyone in this room, let us not isolate ourselves from the university environment when we conduct aviation research. When we have problems in the aviation industry, let us take these problems--such as we have today--to the university environment for solution. Institutions of higher education are an ideal place for the interchange of ideas on aviation problems. A side benefit is the involvement of young people who are going to be the intellect of our industry for years to come. One of the most stimulating things in the world is to have a young "tiger on your tail" really seeking and searching for the answers--one who is not satisfied with tradition.

My subject today is accidents from the pilot's viewpoint. As Charlie Miller mentioned earlier, and his last slide showed, we must take a hard look at what we are doing with the pilot as part of the total loop in the flying activity. The results of an FAA-funded program that we conducted some years back gave some indication as to where our problems really exist. From a massive questionnaire sent nationwide, we learned from a sizeable population of pilots of those flight experiences which they considered most threatening. An examination of the first grouping relates to low visibility, crosswind, low ceilings, malfunctions in landing. Landing problems in varying degrees represent many "fender benders" but the weather problems are making far too many of our fatal accidents.

We tend to think in terms of the pilot as being completely burdened all the time with regulations, ATC procedures, and a host of other activities. We have to do a better job of delineating those things for the pilot that are established as essential knowledge. People, today, with their frantic pace of life are too busy to leisurely assimilate all the "nice to know" knowledge which we say is required to become a pilot. We must do a better job of specifying those areas of knowledge that truly are important. So, when we look at those safety programs, such as the FAA's Sprit of St. Louis, AOPA's Flight Clinic programs, the new Part 61, we must constantly be concerned with honest requirements--not a bunch of phony busy work.

We recently had what we call a Biennial Flight Review introduced into regulation. This a monumental change which we have accomplished as far as regulatory process. The Biennial Flight Review provides the mechanism whereby we can get people close to a flight instructor at least once every twenty-four months--a marvelous achievement. But now that we have it, far

too many pilots, professionals and novices alike, are asking "What are we going to do with it?" It presents a great opportunity which we dare not flub.

Stop and think just a minute. Where else do you have the most wonderful teaching situation in the world as you have with the one-to-one relationship of a flight instructor to his student? Educators all over the world would love to have the opportunity for that kind of a teaching situation, an envious teaching relationship, a close relationship. You do get to know your student; you can establish standards and goals impossible with a large class. Yes, the flight instructor has a great opportunity for a great teaching job, but we must help him. He needs our help. He has a wonderful opportunity to set some standards that will remain with that student throughout the rest of his flying career. The substance of what is taught is most important and the manner in which it is presented is the ammunition for the safety guns of the future.

Incidentally, one of our other serious problems dealing with flight instructors has to do with their role in our industry. The dedicated flight instructors throughout this country who are really doing the job of producing safe pilots, are still the most underpaid in our industry. Suffice it to say, there are many possibilities and many roads for the solution of this. I urge your consideration as to how we cannot only help flight instructors do a better job, but help them be properly rewarded for a job well done.

Now, let us look at the regulations dealing with recent experience. What the statistics boil down to is that many pilots claim they cannot maintain adequate flying skills because it costs too much money. Many pilots claim they feel like they are flying their pocketbook or checkbooks all the time. If you look at these statistics, you find that about 30% of the people sampled had not flown in the last six months. In spite of this, we find that there are people going out and using the aircraft, with greater numbers of passengers and flying longer distances. Thus, we enter into the whole problem of recency of flight.

For some years, we have accepted the regulations of five takeoffs and five landings to a full stop as the standard. It is the intent of FAA that this would be a minimum, not a standard for proficiency. Most everyone will recognize it as such if they stop to think about it. The way this regulation is interpreted is similar to our interpretation of the forty hours for private pilot certification. The point is that whenever we specify a particular number of hours as a minimum, it unfortunately becomes the standard. Therefore, I urge again that we continue to give consideration for adequately describing the kinds of meaningful experiences that will be good to maintain for a satisfactory level of proficiency. Five takeoffs and landings, soon it will be only three, falls far short. We must describe the substance of the experience we deem necessary for an acceptable standard of performance in both proficiency and pilot certification. Specifying well-designed and selected experiences for a pilot -- if we could ascertain what they are, would be a tremendous contribution in the whole area of proficiency. It would also be a boon to the establishing of some meaningful standards for pilot certification.

In addition, statistics reveal that we pilots are spinning in as well as stalling out on final approach. If we did have the aircraft under control up to that point, we are also having a little trouble in the round out, touch-down, roll-out phase due to overshoot or because of crosswind conditions.

Some of the best students we ever produced in our program at Ohio State University were trained during the time when we had an FAA construction program underway and were limited to a single runway operation. We always had a built-in crosswind for the runway in use. Too often we have a situation where this is not the case and the guy thinks that the wind is always on his nose, especially at a multi-runway tower-controlled airport situation. The tower, unknowingly, contributes a great deal to this laxness in skills when they assign an active runway as a function of the direction of the wind.

Traveling around the country, in behalf of the A.O.P.A. Safety Foundation teaching people in a variety of safety programs, I have asked the question: "When is the last time that you really sought out a crosswind situation?" Many people who fly only at the terminal airports have not had that experience for far too long a period of time. When moderately proficient pilots go out to a single runway operation, you know exactly what happens. The pilot is almost certain to have a crosswind, for if it is a single runway airport, they build them that way. They find the prevailing wind and build the runway perpendicular to the wind. As a result, I would urge pilots and air traffic controllers in turn to encourage pilots to occasionally practice a crosswind takeoff and landing, under controlled situations when they are consciously aware of it.

Some other things in terms of developing the necessary landing skills; there is reason to question the amount of time devoted to the teaching program of the landing phase. If you stop to think about it, in the time it takes to round out, touch down and get the aircraft under control, we have very little time to properly expose a student to this critical maneuver. The final roundout, touchdown and rollout are the culmination of everything in flight.

That total process of landing takes about ten seconds. Multiply that ten seconds by 100 landings which is the average number accumulated by most pilots when they achieve private pilot certification. The answer is something short of twenty minutes, the total time experience of a person practicing the critical skills required to land that airplane on the runway. With less than twenty minutes of total time in landings, we had better figure out some ways whereby we can increase this experience. Perhaps, some simulation device to develop landing skills. This is where we could probably save a great deal of money in terms of landing accidents, not to mention the few related fatalities.

There is another problem that we all know only too well. The perennial stall-spin accidents. Yes, indeed, we have all scratched our heads for sometime--what can we do about the stall-spin? I submit to you that one of the biggest problems we face is the falseness of the maneuvers which were contrived to supposedly avoid such accidents. Viewing a spin as an aerobatic maneuver and going out and doing some stalls at an altitude of four and five thousand feet presents a very false teaching situation. Less experienced pilots have great difficulty relating what we instructors do at higher altitudes to those low altitude situations where the records show pilots are stalling aircraft and killing themselves.

It is not at four and five thousand feet under the controlled situation where we have the problems. It is around the airport. It is turning on

final. Somehow, we have to replace these very false and fabricated maneuvers with meaningful experiences which are relevant to the real world of flying an airplane. Do not misunderstand me--these kinds of experiences at altitude are greater thrills when we can do it in aerobatic aircraft, in addition to being great confidence builders, but unless the student sees how they apply to the real world, we have missed the boat.

A last point that I want to make with you has to do with the business of how people are using aircraft today. They are going greater distances. As a result, they are taking larger groups. They are going as families and making increasing use of their aircraft. It has become more of a family-oriented program involving greater numbers of people. But by virtue of the greater distances that are involved, pilots are running into weather changes never experienced before. In spite of the rapid advances in weather forecasting and dissemination technology, pilots are getting into trouble.

We have been teaching weather in classical form. We disseminate weather information in a set of "hokey hieroglyphics" on a teletype machine. This is our present "state-of-the-art" in spite of the existence of the greatest information dissemination system in the world. Look at the language of weather. The last time I saw anything like that was out at an Indian Reservation in Arizona. Somehow, a person must recognize the weather information presented in terms of how he will see it in the third dimension. In that regard, we end up with a typical private pilot viewing weather like this.

In spite of the fact that we want to get information to pilots which will create a meaningful mental picture for the pilot, we still teach classical high and the low as if they are unrelated objects. We have to depart from tradition somewhat and give future pilots some real-world experience. We can provide forecasts and help him visualize existing conditions. But how he views weather is not necessarily either all good or all bad. Rather, the varying shades; the subtleties of the weather are not being taught effectively.

Generally, when we teach the student, we tell him to stay out of the weather. We tell him if he goes out as a VFR pilot and gets in weather, he will be eaten up. He will be destroyed. We teach that "avoid weather" concepts as long as he is a student pilot, and then what? The fellow gets his private pilot certificate and we say "By the way, now you should go out and get your instrument rating and fly in weather." "Get my instrument rating," he replies, "--and fly in the clouds? You just told me to stay out of the clouds, and now you want me in the clouds." Somehow, our philosophy of teaching must be reappraised.

Of greater significance, however, is a common tendency to teach in a far too protected environment missing some of the more significant and meaningful experiences which will mature a pilot. Yes, we insist that pilots get weather briefings prior to each cross-country. Unfortunately, they go out and see things in the forecast that do not come true. There is a credibility gap, to say the least, between what is forecast and what pilots see in the real world. Somehow, we must improve the character and method of weather dissemination as well as the accuracy of the information provided. It is time for a major crusade to bring this about.

What are we going to do? Let me just give you an example of an approach to the problem being conducted at Ohio State. I went up one afternoon to our briefing room, and sat down and listened to our flight instructors greet their students as they came in. This is what I heard. "All right, George, check out 160SU, pre-flight it, and I will be out in about five minutes. It looks like we are going to have a good crosswind situation today for 27-left, so we will go out and work on crosswinds." Who made the decision about the weather? The instructor.

I overheard another instructor say, "Jim, hop out there and get 170SU ready. We are going to take a little short cross-country, Cincinnati, Dayton and back. We have a nice cross-country situation and the weather looks like it is VFR all the way." Who decided what the weather was? The instructor did.

Unfortunately, in all of this time, the instructor--all through a private pilot's training--has been making the decisions when it comes to weather. Then we hand him the private pilot's certificate and say, "Okay, fella, you're on your own." The guy goes out and has little foundation for making decisions because he has had no practice in decision-making. The newly certificated pilot is still a complete novice when it comes to practical weather and the decisions essential to safe flight.

We have tried to change this somewhat, and are now running a little program where the student will decide whether or not an airplane flies on a particular day. That is to say, the student makes the decision about weather. The instructors did not think too much of this at first. Sometimes in a zero-zero condition, an instructor may inquire, "All right, George, what do you think today?" One of our students with a twinkle, replied, "Well, I am game if you are." It is nice to have a tiger, but that is a bit too bold. We have found great merit in the advisability of insisting that students be a part of the decision-making process throughout the flight instruction program. If you stop to think about it, a person has to get up and see what weather is like to appreciate the correctness of one's pre-flight decisions.

Charlie (Boss) Kettering, inventor of the electric starter, who later served on our Board of Trustees, made the observation, "Wouldn't it be wonderful if ever, one could learn to fly and view things in the third dimension?" We are missing an opportunity when it comes to flight instruction because we are not teaching weather in the third dimension. We are not teaching it as people really see it. I think we should seize this opportunity to prepare newly certificated pilots to cope with weather as it is in the "real world."

I think of the experiences one gets in courses like the AOPA Foundation teaches in their mountain-flying course. Real world teaching has been the credo there, and the students are better because of it. Get it in the environment, get it in the real world, have them make those decisions and have them make some bad decisions under a controlled situation with the safety of a flight instructor along with him. Allow them as an instrument pilot see what ice is like. We have a wonderful opportunity as instructors to take people out on certain winter days and pick up some ice. Assure whenever possible that students will learn about the effects of ice so that they appreciate exactly how ice-laden aircraft perform.

Meaningful experiences such as these are ones that a student will never forget. Allow him to really know what it is like to have poor visibility and be unable to see forward. We talk about it, we try to verbalize it, but

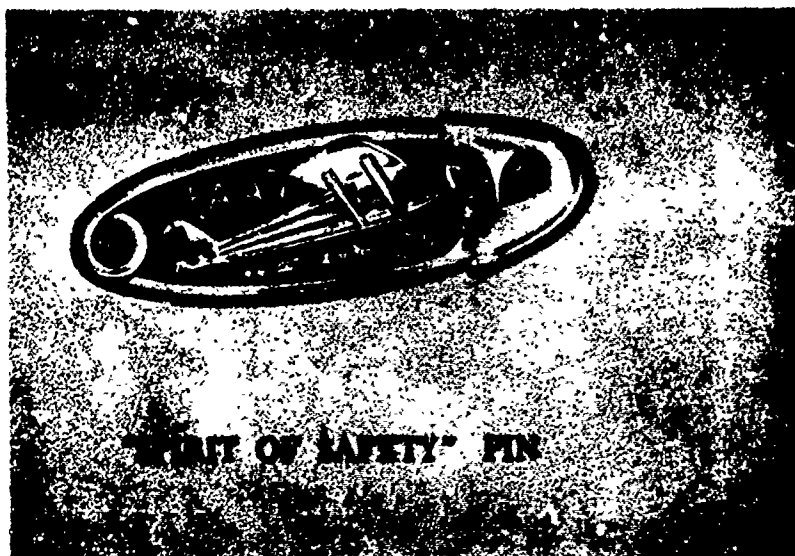
weather is not nearly as meaningful as when a student experiences it first-hand. Have him go out and see what it is like to try and scud run while the instructor is there if things get out of hand.

One of our students had to make the decision to go down to Cincinnati and Dayton on a cross-country. Weather at Cincinnati was VFR, Columbus, Ohio, was VFR, but Dayton was showing some 800 overcast. The instructor knew that he might run into some trouble, but he thought it would be a great experience. The student said he was ready to go, having made the decision as far as weather was concerned, and they departed. They got about halfway down to Cincinnati and they flew lower, 800, then 700 feet above the ground, 600 feet, and the instructor said that things were getting a little tight. Nevertheless, they finally got down to 400 feet above the ground and the student finally said, "You know, I think maybe I better turn around." The instructor said, "Good boy!" The student started his 180 degree turn, and in the process of that turn applied a little back pressure and pulled himself up into the clouds. The next thing that happened, the old graveyard spiral dive, and with that the instructor took over. There is no question on the part of the instructor that his student would have killed himself. That student has subsequently articulated to his peers and others in our flight operation about that experience. It turned out to be one of the best things that has ever happened. Having experienced that situation he wants no more of the same. Furthermore, he is motivated to go on and develop the skills and knowledge appropriate to handling an aircraft in weather like that.

We acknowledge the desirability for pilots to be able to make split-second decisions as far as weather is concerned. The more real-world weather experiences that we can introduce into the flight training situation will give that person a fund of experiences to draw on in order to test his new experiences against past experiences. It is a deadly combination when we turn a brand new private pilot loose never having had to make a decision, having learned to fly in a completely protected environment.

When you stop to think about it, pilots are a proud group. Pilots all over the country are proud people, and that can be a great strength. We can capitalize on this pride if it drives us to be better. We can turn that pride into the greatest opportunity for safety. I am so delighted that we care enough that we will take our precious time to come and have an interchange of ideas as you people have here, to get excited once again about making the accident record even better than it is today.



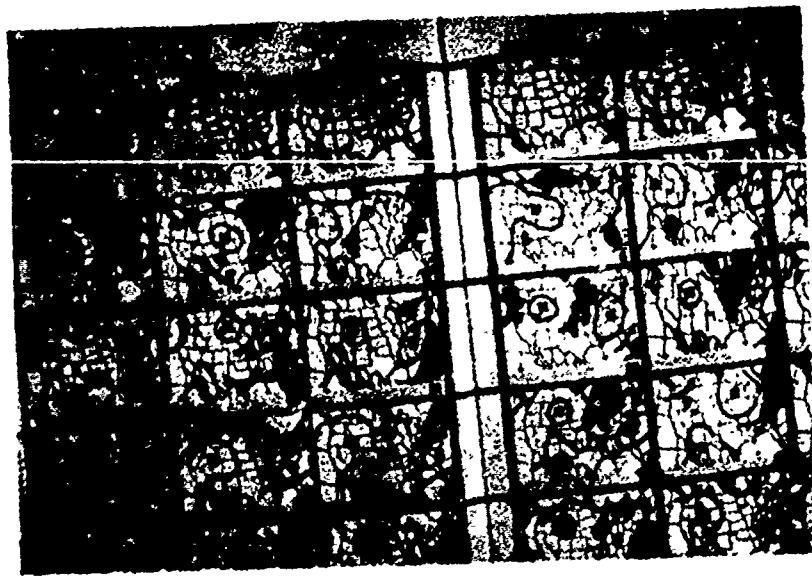


The Instructor

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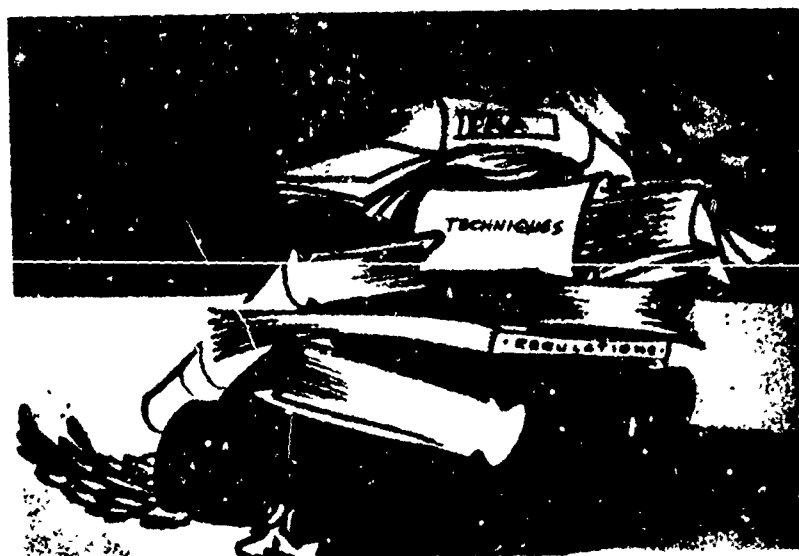
Weather Wise



Weather Charts



Cost Consciousness



Pilot's Dilemma

DISCUSSION - SESSION J

THE GENERAL AVIATION ACCIDENT RECORD

Jerry A. Shrout  
Vice President, Claims AVEMCO Insurance Company

I will talk about some ideals and know they cannot be met. We will never prevent accidents. I think we all realize that. I would like to see the NTSB get more heavily into general aviation accidents, but obviously they cannot do it. They do not have the manpower. There is no way they can with the force they have. I would love to see them get human factors more in general aviation accidents. About two years ago, I did a very brief study on fatal accidents that my company insured. I requested a division of motor vehicles report and a credit report on the pilot. I did this in about ten or fifteen cases. A significant number came back with a driving record you would not believe and a credit record you would not believe. My message here is that if the guy is not responsible in one area of his life, what makes us think he will be responsible in the air? I think the psychological people can do something with this, and we can weed them out before we have them in a plane.

I would like to see the manufacturers do more human engineering in the cockpit environment. One small point on that, is we all know that on impact if we have a seat belt on, the legs fail upward. Go out to any general aviation aircraft and look under the instrument panel and see what happens to those legs when they come in contact with the airplane. An FAA flight surgeon in Texas has an unbelievable series of color slides. I do not recommend viewing them for all people. I will pick on Jack a little bit, because I see daily the lack of adequate flight instruction and I think this will continue to be so until we make flight instruction a profession, treat the instructor as a professional, and compensate him adequately. We have too many part-time instructors who are instructing for a year or two to build time. I know people like Jack have worked hard to attempt to upgrade this. We need more. The best example I can think of is a 172 pilot who flew from California over the Grand Canyon. He ran a tank dry, switched tanks, and he could not get the engine started. He made a forced landing in the Canyon. Luckily, there were no injuries. My investigator went out and interrogated him, and he got the story from this fellow in such a way that it is believable that his flight instructor taught him to fly that way, to take off on one tank, fly until it is dry. He never checked the other tank which had a blockage in the fuel line. It was impossible to get fuel through the line. I believe the man was instructed in that manner. I know that some of the things I am asking for are not going to happen because in the real world you just cannot meet the ideals. I would hope Chuck would get some more manpower, and I would hope that we could get some more human engineering and human factors in the investigations.

COLLINS: I have one observation I would like to make from the material that was presented. I think we need to be more responsible to problem areas that are defined in and by the accident statistics. Chuck mentioned my interest in the multi-engine accident rate. I have paid quite a bit of attention to that in the past and still do. The fact of the matter is that people buy multi-engine airplanes because they think they are safer, and from a fatal accident standpoint, they wind up less safe than a single engine airplane. We have that in black and white in the accident statistics, and yet everyone seems to look at that and they go on to the next question. This is also especially true when new aircraft come out. When a new airplane is introduced, some go into service and have no problems. Others go into service and have initial problems and continue to have problems, and it seems that these problems are apparent in the accidents the airplanes have. After the dust has settled on two or three of them, we should get a message that we should do something. Actually, when you look at the situation, it sometimes takes three, four, five or six years to react to a problem that an airplane very obviously has. By the time the second or third one has an accident some action should be taken before too many of the aircraft are sold.

ALLEN: We are working on a project to investigate and identify and substantiate the need for improvements in general aviation aircraft engines and related things for the purpose of improvement in future light aircraft design. At this point, we have eight years worth of selected NTSB data which we have analyzed using the CHI square as done by NTSB in 1967. We have studied 35 makes and models, 17 of which are in current production. We have looked at the number of accidents per hundred thousand hours of flight. We also have looked at twelve accident categories and obtained those frequencies of accidents that are significantly high and those that are significantly low. The analysis shows that those aircraft that were bad eight years ago are still pretty bad right now, and the ones that were good are still pretty good. We looked at the characteristics of aircraft design such as high wing versus low wing, retractable versus fixed gear, tricycle gear versus tail wheel, multi-engine versus single-engine. But we have to look further. This is the reason for my getting up here. We have gone into the 17 aircraft in current production and have obtained useful characteristics and some aerodynamic characteristics and we have gone through the procedure of trying to correlate the accident rate with the characteristics. The characteristics are correlated with the accident type rather than overall accidents, and we are coming up with several significant correlations. We hope to do something about recommending some changes or looking at the aircraft in a constructive way.

QUESTION: This is addressed to Chuck Miller. Does the threat of product liability and lawsuits in any way inhibit your findings? In the

case of a manufacturer, modifier, or whatever it happens to be, are you afraid to publicly say what may have been the cause of an accident because of the jamming of the courts with product liability problems these days?

MILLER: I hinted at this a little bit when I made the point that I felt for the most part that parties to the investigation were very co-operative. We are not immune to the growing liability problem. We have been talked to by everybody in the world, plus I personally have had this subject as an avocation for many years. One of the reasons several of us personally believe we want to get rid of the probable cause is for just this reason. We think that probable cause as the Board puts them out has been used by litigants, not in the court per se because for the most part, this is not allowed by the law. But it certainly has been used in the back rooms where negotiations are made. Whether this affects our investigators to any significant degree, I honestly do not believe it does. I just returned last week from another field office tour of some of our West Coast offices, and it so happens this particular subject came up, because I was asking them for whom were they investigating. As long as we stick to facts, conditions, and circumstances, and as long as we analyze not for proximate cause but for probable cause as we have defined it earlier, we are acutely aware of the possible ramifications of what we do. The approach that we try is to keep it even. In other words, if we stay to facts, conditions, and circumstances, and if we insist that when a part is being examined, it is not being examined by one person only, if people have an interest and involvement in this, let them come around and look at it while it is being tested. We are trying to keep it out on top of the table and, if we do that, that is the best we can do as an investigating agency.

COMMENT: I picked up in your discussion, Chuck, that you might have liked to have said that pilot error caused 83%, or whatever that big number was up there because we really did not want to say that it was the pilot error that flew it into the IFR conditions and it was the lack of inherent stability that caused him to graveyard spiral.

MILLER: What we try to do in our business (keep in mind that we are there investigating to prevent accidents) we are looking for "causes" which are subject to remedial action. I could not care less, and I try to convey this to our investigators, whether they find something which conveniently fits a broken regulation or a standard that has not been adhered to. We are looking for things that are amenable to corrective action. That is why I personally abhor the idea of using that type of slide and saying, "See, 83% pilot error," because it could be that we may classify it that way so we can get at the data later. But something that is capable of

being remedied simply may not be in that area. Jack will tell you he has some things he can do with pilots, but he will also tell you there are some things he cannot do. Our approach here in thinking is a different approach from what the lawyer is after. The lawyer is after proximate cause so that he can match that with damages and failure to meet standard of care and duty and all that sort of stuff. We are not. At least we try not to be. But there is a common factor, and that is the facts, conditions, and circumstances that are derived from the investigation. From that point on, they are used by the safety cats and they are used by the legal cats, and we know no other way to handle this in the interests of the public except keep it above board.

QUESTION:

Is it known what factors accounted for the reduction in spin-stall accidents? There was one thing we did that was very positive when the fatal accident rate went down 48% to 27%. We have done something well. Are we sure we know why? This happened despite the fact that the manufacturers did not come up with improved spin-resistant models. What is it we did right to achieve this and can we do more of it?

The second question, do we know the relationship between vehicle defects and crashes? It has been assumed that a defect causes a crash, but we had two instances where a non-defect caused a crash. The Aircoupe is an example of a good airplane that was pushed too far by the pilot. In another instance, operations on a single runway airfield actually improved the pilot's experience over dual runway operations. So the question is, do we really know the relationship between vehicle defects and crashes?

The third question is how often does distraction of some sort cause accidents? But really distraction from what? If this is a Holloway type of instrumentation and if it is that one is looking from one instrument to the other, perhaps there ought to be a second instrument where it is all presented.

ALEXANDER:

I think part of the answer to the first question you would have to look at the summary perspectives in going from 48% to 27%. There is no discreet answer. It does involve state of the art which goes back to the airplane itself. We know we have better aircraft today. It involves sophisticated techniques. We do not know clearly. If we did, I think we would have a nice packaged answer to all the stall-spin problems.

MILLER:

There has been some work we have done similar to that of NAFEC in terms of engine failures, and certain engines in certain



aircraft and their installation, there was some correlation work done there. The problem is that it is very difficult if not impossible to pin a cause to an accident.

**ECCSPUEHLER:** One of the things that we must be doing all the time in the flight training situation is to try to get a student so that he can develop a variety of canned decisions to use when he has to make that decision under fire, which is the worst time in the world. We do not think well under fire. Under stress, we are just absolutely lousy, and we have all kinds of research to document this thing, how the action in performance is a function of stress. But the biggest thing about this is that ~~here~~ we are in the accident situation, and that is when we are usually at our worst. So if we can do anything to unload the pilot such as improving the design of aircraft or by improving the procedural task that we teach him by getting him used to this environment so that he is not loaded stressfully as a function of fear. All of these things will contribute to the objective we all desire.

**MILLER:** We may not have the capability, because the techniques are difficult in general aviation, but we have learned some very, very significant things in air carrier work by using the cockpit voice recorder. If there is one overwhelming finding in my judgement that deals with human performance that we have gained from cockpit voice recorder information in air carrier aircraft, it is that the guys never knew what hit them, or at least they did not know more than a few seconds before they impacted. Now think about this a minute. This gets back to what Jack is saying, that they are not either trained or they are distracted at a very critical time. We have positive evidence of this. This is not just conjecture. We know that the L-1011 in Miami that seven seconds before impact the Captain was heard to say, "Hey, what's going on here?" We know in a case that has not been published yet that although they were making an approach to a relatively sea level airport and many miles from there co-pilot says, "Hey, how come the radio altimeter says 400 feet?" and they were at 4500 feet. We know of another case that has not been reported yet that the crew literally did not know where they were to the point they were asking, "What's the minimum en route altitude," and the man was cut off in mid-sentence when he said the minimum en route altitude out here is 44 --- stop! And they were down around 2000 feet. My point here is that whether you call it distraction or whether you call it not being cued in, it means that something is going on in an abnormal sense that that crew does not have some thing or some body tapping him on the shoulder and saying, "Hey, you're in trouble." I think that gets back to Jack's talk about his instructing in the real world sense. I do not know if that L-1011 captain in a

teaching environment had somebody turn off his auto pilot and nudged it going down hill. I do not think they did. We asked that question, but you have to get these guys to understand the real world variations in the book. How you do it in training, I do not know, but I think your point is a fantastic one and I think it applies to all parts of aviation.

COMMENT:

The problem in those instances is that it is a cumulative situation, and that then addresses what Don mentioned earlier. If it is possible to screw something up, under stress is when you are going to do it. I can think of aircraft we fly on a regular basis where the throttles and props are reversed, two from the same manufacturer, essentially the same size aircraft. If you have two or three other problems and then something happens in that environment, it can ruin your whole afternoon! What normally happens in many a proved stressful situation is the important thing.

QUESTION:

I would like to know if anyone has any idea as to how much energy is being expended in training or hardware development in the following diverse areas. A report concerning incidences of carburetor ice was recently published by the NTSB. There were still a significant number of reported incidences. This seems like an old problem that should have been solved many years ago. What are we doing to mitigate this problem now in training or hardware development to notify the pilot that he is forming ice? The other subject concerns ditching. Recently, I took a look at some of the ditching statistics of general aviation aircraft; we still have had quite a sizable amount of them due to engine failure or engine malfunction. Looking back to the factors involved in engine malfunction, over 90% of them involved fuel exhaustion or fuel mismanagement. It seems that there may be some solutions to this, and I wondered if we are doing anything to train pilots so that they do not get into this predicament of running out of fuel while over water, or are we developing any hardware to warn him of some impending fuel exhaustion so he has sufficient time to head for his landing. Is anything going on in this area?

KEMP:

In relation to the study that he referred to on carburetor ice, it was an old problem and I guess it will always be with us and I guess you have to train and retrain pilots in what to do. It is amazing to find out that pilots will go through an approved ground school, flight check, get their private ticket, and you ask one of them what they do when they pull the carburetor heat, and you would be surprised at the answers you get as to what they are actually accomplishing. Most of them think if the rpm drops, it is working, but what if this happens in flight, what do you do? It is still working. They are not taught properly to understand the significance of the difference

in reading when you apply your carburetor or heat and when you remove it, so I guess basically this is part of our accident prevention program that we continually try to reach the maximum number of all pilots with the things that are old hat to many pilots but it is surprising how many things they have forgotten. So it is a continuous program retraining or making material available for their review.

MILLER: The motivation for that study was exactly what Don said. We looked at the data and said, "This thing is still with us." It is about time we put some more information out with a new date on it, because we had a sensing from our field personnel that people had forgotten it. It sounds crazy but that is exactly what it is. How much of this is contributed to information contained in the handbook of new aircraft where they basically tell you not to worry about it too much. It is true. In that engine, you do not have to worry about it too much.

COMMENT: There is a training aspect to this. Would you agree that there may be some room for some hardware development, some low cost gadget that will kick a pilot in the rear and say "Hey, these things are going to happen. You had better not draw from your training or you will renunciate what you do by the numbers."

COMMENT: I think a low-cost carburetor ice detector does not exist.

FRED WEICK: I would like to talk a little bit about this spin-proof airplane situation. Donald Kemp mentioned its poor record in this stall-spin report, particularly the NTSB report. I naturally was a little perturbed when I saw the report, and this is an example of how difficult it is to classify all these things in a general way and come out with the right answers. So I have taken the trouble of going into the briefs of every individual one of the thirteen accidents that occurred in the so-called spin-proof airplanes, such as Aircoups, the 40's and the Allens. There were thirteen accidents in the three years in that stall-spin category. I have found ten of the thirteen so far. Of those ten, only one was a fatal accident. That one had a fire after impact. There were none listed as a spin accident. They were all listed as stall or stall mush. Nine of them were listed under the minor or no injuries category. So when you look at it from that viewpoint, 10% were fatal of the so-called stall-spin accidents that really were probably mush accidents because these airplanes had lateral control all the way to the stall. It was not that you cannot flip-stall them. If they were properly made, you could not maintain them in a stall, but you can always flip-stall them and get a stall condition. Considering that the general run of airplanes -- I did not have the exact information from this NTSB report, but I put together the figures as best I could -- it

looks as if over half of all the stall-spin category accidents for airplanes in general are fatal or have fatal results. So the 1/10 as compared to the 1/2 still looks as if it may have been worthwhile investigating the spin-proof and stall resistant idea. On the other hand, there are a lot of accidents with that type of airplane. Many of them occur because people do not quite respect it the same as they do the general run of airplanes. They have had the feeling that they could be a little freer and they use up the margin of safety and then you don't have it. It certainly has the same disadvantage that all airplanes have at this time, and I would like to see something done about it. In particular, at angles of attack above that for minimum power or above that for maximum rate of climb approximately, the sense of the longitudinal control reverses and a pilot is still inclined to pull back when he should be pushing forward and I think we should do something in a general way to avoid that situation, to keep him out of that situation. I will just state this in general terms now, but I do think that improvement in the airplane along that line is still possible and that we should try it. Although there is a great disparity of manpower, say 50,000 people in the FAA directly involved in accident prevention and maybe 100 involved in accident investigation, is this or is this not a desirable split for the industry as a whole.

**EGGSPUEHLER:** The budgets we have right now are lacking in due support of accident investigation. We do need more people. I wish we could enlist people in the accident investigation process. For instance, I see where cadres of people around the country who are in the industry and concerned in the whole matter of aviation education -- one of the greatest experiences would be some graduate students at Princeton or Illinois or wherever it would be, to be invited to be a part of some of these accident investigation teams so that they too could be stimulated from the standpoint of looking at all of the problems as you are looking at all of the problems as you see them in the accident scene. Yes, I would like to see more budget allocated to accident investigation. In the area of accident prevention, we have had a new effort. It is going to be a long time before we see the results of Pete Campbell's work, but there is no question in my mind intuitively that that accident prevention program is going to pay off in spades. They both need more support. I wish they would enlist some free support from the university environment as well.

**COMMENT:** We in the insurance business must agree that we are not completely satisfied with the accident investigation process in general aviation. Under Part 121 operations, there is no question. It has been excellent. Professional trained investigators from the NTSB and FAA. I have wondered from Don how many actual trained experienced professional investigators worked

on the other 3900 accidents per year in general aviation. You said somewhere between 600 and 700 fatal accidents that the NTSB investigates. How many of the accident investigations in general aviation contained in the report come from the owner-operator or an FAA inspector? Don, how many actual professional investigators do you have throughout the country?

KEMP: Over 50,000 if you want to look at it from the broad sense, but I know what you are referring to. We use approximately 4,000 professional investigators.

QUESTION: In other words, everyone of these general aviation accidents now is investigated by a professional investigator as opposed to an FAA inspector pulling the additional duty?

KEMP: Let me explain one thing. There are certain fender bender type actions that the report of the owner-operator is accepted. So other than preparing the report, there is no investigator involved. On the others, there is always an investigator involved or normally two or more on each general aviation accident.

COMMENT: We have found from some of our experiences that the investigator on the scene does not have the enthusiasm that probably you think they have! I have found from personal experience that many times he says, "I have got to get this done. I have to get back and do this at the office, so we'll fill out the forms as quickly as we can." From my standpoint, I am not happy with such an investigation. I would like to see the professional full-time investigator whose whole career is active investigation. This is a dreamlike zero accident rate. But we feel that accident investigation in general aviation should be improved.

**SESSION II - General Aviation Design and Safety**

**R&D Overviews**

**Chairman, Edward Seckel**

**Professor, Dept. of Aerospace**

**and Mechanical Sciences .**

**Princeton University**

## Crash Survivability

P. Frank Castellon

Manager, Crash Survivability Program  
Federal Aviation Administration

This morning, we talked about the accident record in general aviation. We talked about some of the reasons why we have to interpret that accident record correctly. I think we can all attest to the fact that the safety record of general aviation airplanes has improved over the last ten to twenty years. The airplanes are better; the pilots are more competent. However, we would still like to improve this accident record further.

Over in the R&D side of the house in FAA, where I work, we looked at what we could do to try to reduce the number of crashes and the serious injuries and deaths which are occurring in general aviation today. We came up with two different approaches. The first approach is to try to prevent the accident from ever happening. This has been the traditional method by which FAA has sought to maintain safety in general aviation and, in fact, all air transportation, and our record is good. But because we realize that accidents will happen, we must improve the survivability of the occupants of these airplanes. As a result, we have been working on a crash survivability program for general aviation aircraft.

First, I want to tell you a little bit about the accident prevention R&D that we are engaged in at FAA. Primarily, we are concerned with the stall-spin problem because it comprises the largest group of accidents. We are trying to introduce some innovative thinking into this area. One of our tactics is to try to come up with some new and novel ideas on how to prevent stall-spin accidents in general aviation airplanes. The FAA is tackling the stall prevention side of the problem and NASA is working on the spin side of the problem. The FAA is particularly interested in the aerodynamics of the stall and methods of preventing it. One development undertaken by Texas A&M University involved the installation of a spoiler on the lower surface of the horizontal stabilizer of a single engine Piper PA-18. This system includes a device which senses the angle of attack of the wing. Whenever the angle of attack of the wing approaches the stall, the spoiler actuates and limits the capability of the horizontal stabilizer and elevator combination to maintain this high angle of attack. As a result of this action, a stall and the inevitable spin are prevented.

Currently, we have contracted with Texas A&M to install this same system on a Piper PA-30 airplane to study its effectiveness on a twin-engine slab-tail airplane. We want to evaluate it in both accelerated and unaccelerated stalls. In addition, we are going to take a complete look at the flight envelope of the airplane with this spoiler installed to see if it does, in fact, prevent the pilot from achieving a stall.

The next subject I want to discuss is the crash survivability program that we have set up. First, let me say that we want to involve general aviation manufacturers in this program as much as possible through contractual R&D efforts. We are encouraging these manufacturers to exchange information of common interest with universities and other flight safety groups

that perhaps have a great deal of safety technology available in order that we can assist the manufacturers to apply this technology to general aviation aircraft design.

We are also developing analytical criteria that may be used for improving structural design without resorting to expensive full-scale crash tests. The analytical techniques used by FAA will be based on full-scale crash tests and destructive component testing, which we are planning to do ourselves. Once the results are verified, we will distribute the information to manufacturers and to the industry in a format that will enhance its utilization at the desk of the engineer and the drawing board of the designer. In other words, we realize that we have got to make the information accessible, understandable, and easy to use if we hope to make real progress. In this program, we plan to review, incorporate and modify techniques developed by the Armed Forces and NASA to improve the occupant's survivability in an accident. In addition, we plan to evaluate concepts such as the airbag, currently being considered in the automotive industry. For example, we are trying to come up with the best structural analysis that we can use to define a survivable crash, and which types of energy absorption mechanisms will protect the pilot and occupants of a light airplane from being seriously injured. We are interested, for instance, in adapting to general aviation use the crashworthy fuel system that the Army has developed for its helicopters as a deterrent to post crash fires.

We have contracted with Dynamic Science in Phoenix, Arizona, to set up a computer analysis and simulation of a total seat, occupant, and restraint system concept. We have essentially three parts to this analysis. The first part is a model of seats found in use today in general aviation aircraft. We have modeled five different types of seats in this part of the program. The second part of this analysis consists of modeling the restraint system. We have two types of restraint systems; one which has single-double lap belts between the main seat belt and shoulder harness and another system which provides interaction between the restraint system and the floor and the seat. The third part of the simulation, and the most complex, is the model of the occupant. Ideally, we want to simulate a human being in the analysis of man-machine reactions during a crash. But in a test situation, we use anthropomorphic dummies, for obvious reasons, and they don't always faithfully simulate a human occupant, which makes difficult correlating crash tests data with computer predictions. We are trying to resolve the dummy-human discrepancy by developing a more human-like dummy.

The work leads directly into aircraft crashworthy analysis for which we are about to issue a contract. The task is to develop an analytical procedure for the complete airplane or at least those portions of the airplane which affect the crash survival of the occupant; the cockpit environment, the wing carry-through structure, and portions of the forward and aft fuselage. This analysis will be completely verified by full-scale crash tests.

The results of all of this work will be published in a handbook. The first phase has already been published by Flight Standards, and summarizes all of the existing crashworthiness information for general aviation airplanes. We will be revising this handbook as our work is completed.



The next topic I would like to discuss is airbags. I think most of you will be driving automobiles in the latter part of the 1970's that will be equipped with airbags. We are looking at modifying these airbags for future use in general aviation aircraft. The present position of the FAA, however, is that existing technology, the seat belt and the shoulder harness combination, is just as effective as the airbag, and can provide immediate improvements in level of safety. In addition, there are some developmental problems with the airbag that have not been solved. Specifically, we must confirm the reliability of the sensor mechanism which actuates the airbag during a crash as well as the reliability of the airbag itself. Our primary concern is inadvertent actuation of the airbag in flight, especially during an approach to landing which could have catastrophic consequences. We are encouraged by the fact that the reliability of the automobile airbag seems good and it has been approved by insurance companies who have paid their own money to put thousands of these airbags into automobiles. Although their effectiveness in automobiles proved to be excellent, we feel the environment of the airplane is a bit different from the automobile and further testing must be done. Consequently, we are continuing to look at the airbag, but in the meantime, we are concentrating on improving seat belts and shoulder harnesses.

Most of our experimental R&D work will utilize FAA and NASA facilities at NAFEC and Langley Research Center. We are testing restraint systems using the catapult at NAFEC. We also have a drop tower testing rig at NAFEC which can be used to simulate vertical drops. In addition to that, we have developed a static test facility at NAFEC which is capable of applying three dimensional vectors statically and which can give you the force deflection history of each of these vectors at once. We intend to supplement this work at NASA Langley Research Center.

All this work will culminate in full-scale crash tests to be conducted at NASA Langley. The facility that will be used for this work is the same one used to test the lunar landing module. We have removed the lunar surface simulation and have essentially a concrete runway, and we are going to be testing airplanes by hanging them from the second level of the tower and swinging them down into the prepared runway surface, releasing them just at the point of impact. The FAA will be conducting tests on seats and restraint system using dummies in the cockpit, while NASA will be testing the structural integrity of the airplanes.

We also have obtained several condemned aircraft from Piper which were inundated by flood water during Hurricane Agnes in 1972. This water damage prevents them from flying again, but they are especially well suited for doing full-scale crash tests.

In conclusion, I feel that because of the projected growth rates that the general aviation industry is talking about in the next ten years, we must do a better job of improving aircraft safety. Although we have been doing a good job, the task is bigger because of the projected increase in airplanes and pilots. In order to maintain and improve upon the general aviation safety record, we need a sophisticated and hard-hitting crash-worthiness program. I believe that the FAA and NASA can meet the challenge.

# **GENERAL AVIATION CRASHWORTHINESS**

## **FAA/NASA INTER-AGENCY AGREEMENT**

### **THE FAA AGREES TO:**

- DEVELOP AND VERIFY AIRPLANE AND OCCUPANT-SEAT ANALYTICAL TECHNIQUES USING CURRENT TECHNOLOGY
- DEVELOP A DEFINITION OF DESIGN CRASH ENVIRONMENT
- DEVELOP IMPROVEMENTS IN CURRENT CRASHWORTHINESS DESIGN TECHNOLOGY

### **THE NASA AGREES TO:**

- DEVELOP AND VERIFY ADVANCED ANALYTICAL METHODS
- DEVELOP A FULL-SCALE CRASH TEST FACILITY AND TEST TECHNIQUES
- DEVELOP COMPUTER TECHNIQUES SUITABLE FOR USE BY GENERAL AVIATION MANUFACTURERS
- EVALUATE CRASH ACCELEROMETERS FOR USE IN A LARGE SAMPLE OF GENERAL AVIATION AIRPLANES

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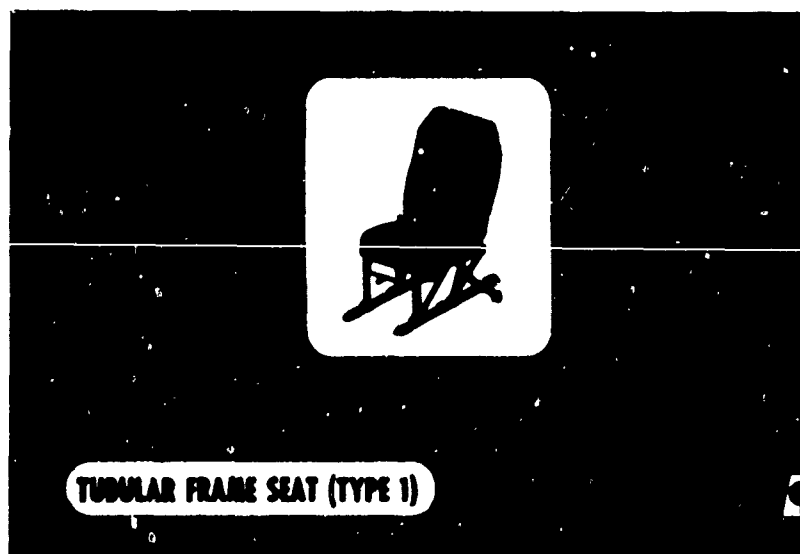


Fig. 1

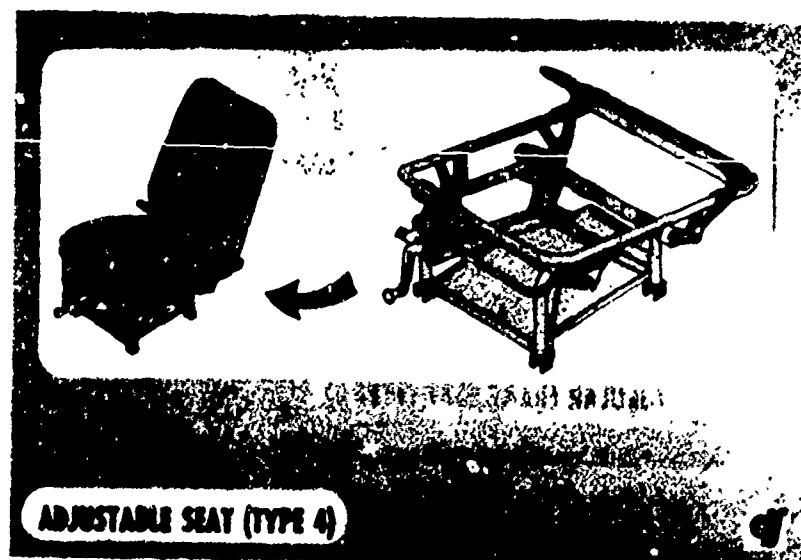
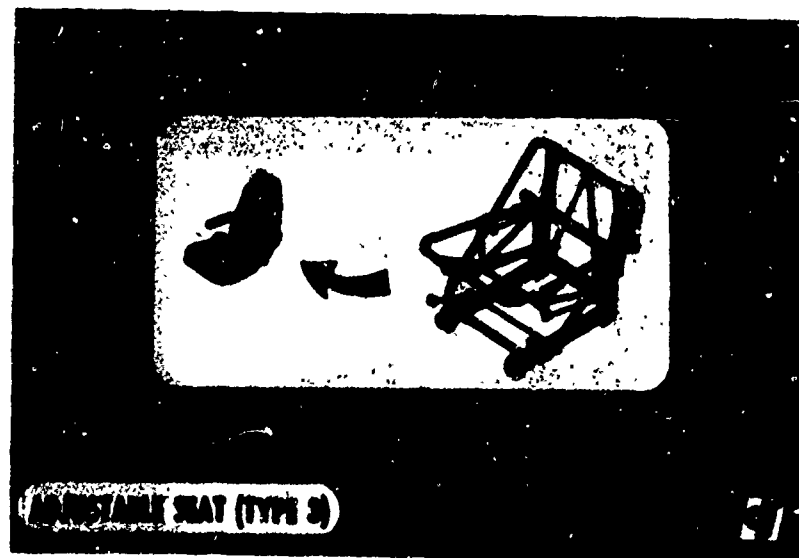


Fig. 2

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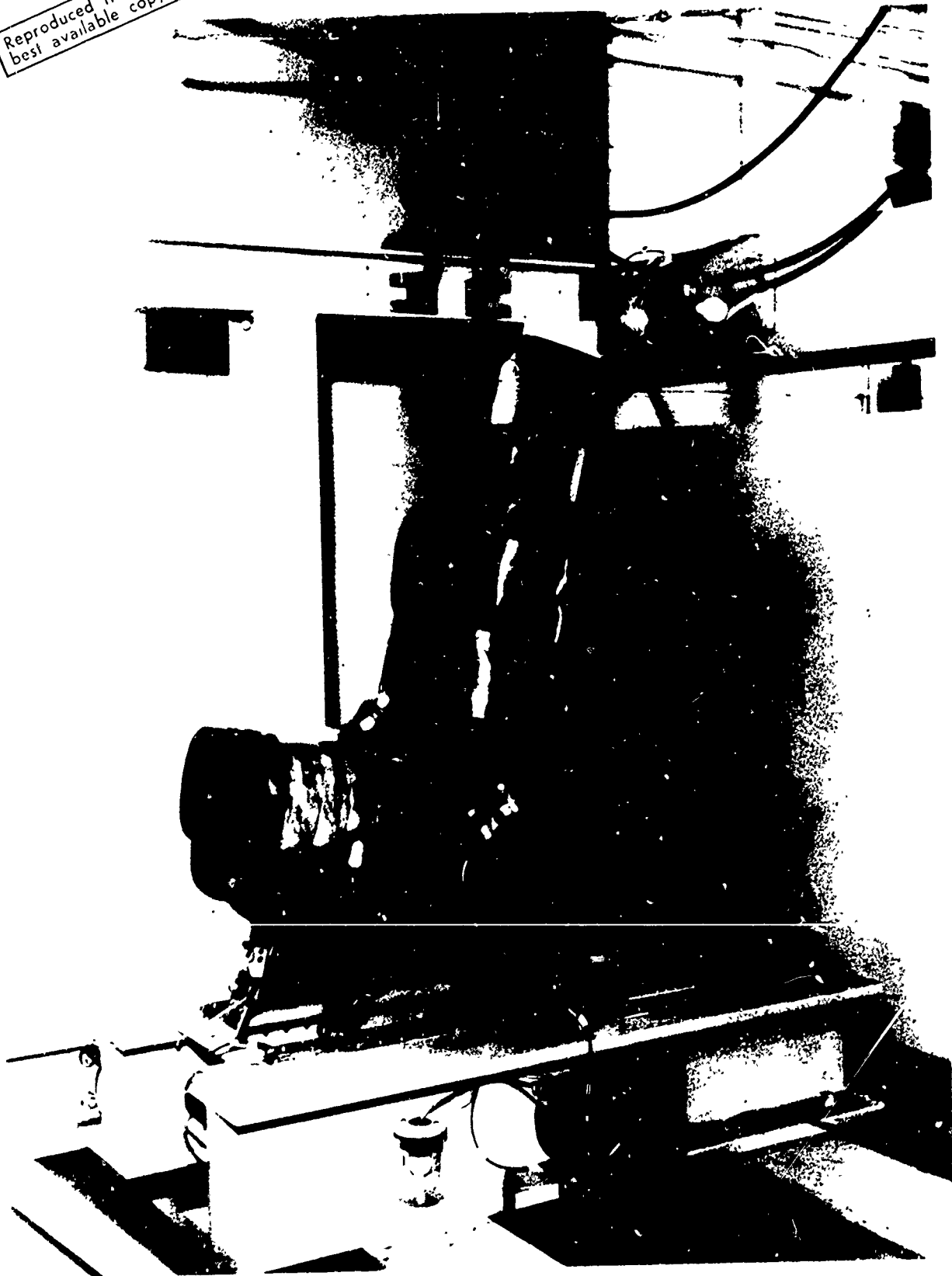


Fig. 3 - General Aviation Seat Compression  
Test Setup at NAFEC



Fig. 4 - General Aviation Restraint System Test Test Set Up Using  
Catapult at NAFEC



Fig. 5 - Hurricane Damaged General Aviation Aircraft  
Slated for Full-Scale Crash Tests

## General Aviation Handling Qualities Research

David R. Ellis

Manager, Flight Dynamics Research

Department of Aerospace and Mechanical Sciences

Simply put, the subject of handling qualities deals with the ease and precision with which an airplane can be flown. It is a complex subject dealing not only with the dynamic characteristics of the machine itself but also with the characteristics of the human operator. In view of the ever increasing number of airplanes being built, sold, and operated, one must conclude that at least some useful state of the handling qualities art must exist. That is, manufacturers have the ability to build sufficient utility into an airplane to make it attractive to buy, and people of average skill and intelligence are able to use it. This denotes an apparent level of success.

I think it must be noted, however, that a great deal of research in the handling qualities area has been going on over the past decade, some of it specifically on handling qualities of small airplanes. It is fair to ask the question then, why the research? Are there some real problems hidden here? Is there new technology coming along that we can usefully apply but just haven't seen in existing airplanes? Are there some fundamentally new things to learn, new approaches to design? I hope by reviewing this recent work that some of the answers to these questions can become clear.

For the purposes of the discussion here, it is convenient to categorize the kinds of research activities that have been going on. The first is testing to identify problem areas. A second category involves development of new devices or concepts. A third category and maybe the one that is least known to the audience here this afternoon, is the definition of rather generalized handling qualities criteria. I would like to discuss each of these categories in turn and give some examples.

Testing to identify problem areas usually involves instrumenting an airplane and doing flight tests to measure such things as stability and control characteristics, control forces, and pilot activity. A prime example of this was the evaluation of the handling qualities of seven general aviation aircraft carried out at NASA-Flight Research Center in the early 1960's. Several areas of deficiency were pointed out. I think it likely that none of these was a surprise to the builders of the airplanes. At any rate, this particular study started some dialogue between NASA and industry which has led to several productive programs.

One endeavor which I would like to make particular note of is the full-scale wind tunnel testing of representative light plane configurations. These now number something like six or seven and represent information that is invaluable in the design process and in the estimation of flying qualities; it will be of great value in the future. NASA flight testing continues at Edwards Flight Research Center. A Piper PA30 was acquired and has undergone extensive flight evaluation. NASA-Langley has recently become involved in this problem identification category of testing with a



Cessna 172 and a Piper PA28. This is operational testing rather than flight testing in a conventional sense, in that the airplane is turned back to an operator and a great deal of data is collected on just what happens when the airplane is operated on a day-to-day basis by ordinary pilots. This is a little different from taking an airplane, instrumenting it, and letting test pilots fly it. I understand this will be reported in the future.

The category of exploration of devices and concepts. The first example was the work carried out at NASA-Langley and under FAA sponsorship by Cornell Aeronautical Laboratory on the wing leveler autopilots. Simple devices utilizing a tilted rate gyro to augment the spiral stability of the airplane were installed in the aircraft. At the time the work was done, the devices were commercially available and these two programs simply were evaluations of commercially available equipment. The tests were positive in their results and the equipment became at least optionally available on other airplanes.

In this category, spoilers for flight path and roll control have been explored in more recent research. Here we have a device which was well known in its application to sailplanes and in some transport aircraft for flight path control. As far as small powered airplanes were concerned, the spoilers were something that had been tried and rejected many times in the past. I have run across references dating from 1921 for full-scale (unsuccessful) trials of these devices. They hold such promise, though, that a few years ago NASA-Ames contracted with Aeronautical Research Associates of Princeton to install spoilers on the Beechcraft Musketeer airplane.

This work confirmed the known performance advantages of such devices. It also identified the importance of integrating the spoiler control properly with other controls. This turns out, in fact, to be the key to making such devices a viable flight path control. Simply putting an extra handle in the cockpit to operate spoilers is not a good thing to do for it invites confusion at critical moments. Properly integrated, they can be used to great advantage throughout the approach, touchdown, landing and go-around phases of flight.

A second example, also sponsored by NASA and carried out at the University of Kansas, is the Red Hawk airplane, a modified Cessna Cardinal. Dr. David Kohlman, who directs the project at Kansas, is with us and I am sure he will be glad to talk about the airplane with you. In this program, an advanced technology wing was designed and built in an attempt to optimize the wing for cruise without losing low speed handling or performance. Spoiler roll control was chosen in order to be able to utilize full-span flaps. However, the possibility of using spoilers for flight path control was not lost upon the researchers, and this capability was built into the system. Flight testing is underway on this project.

Another example in this area would be the advanced control systems and instrumentation research carried out at NASA Flight Research Center on their Piper PA30. The systems are rather exotic by normal general aviation standards, but nonetheless within the state of the art. They include attitude command and rate command control systems, and flight directors. The results are promising enough that further development and real attempts to make low cost versions seem warranted. A more recent effort sponsored by NASA-Flight Center and carried out at Kansas is the development of separate surface stability augmentation which simply means taking a small part of a moment

control, such as an aileron and driving it with a servomechanism independent of the mechanical control system. It can then provide attitude stabilization, increased damping or spiral stabilization, while leaving the pilot with aerodynamic over-ride capability. A full-time automatic control system is thus available without the system complications, such as redundant servos, which are usually required.

Another effort, which has not been flight tested is the constant-attitude aircraft concept being studied at North Carolina State University, under NASA-Langley funding. A concept which is in the flight test stage and which Frank Castellon mentioned briefly, is stall suppression by limiting tail lift. An effort which started out with Army support, then moved on to FAA sponsorship. This project is being done at Texas A&M and I am sure you noticed the PA30 airplane at Forrestal with this device on it.

Let's proceed to the third area of research. This is the one which I will dwell upon at length simply because for this particular audience it may be the least familiar. The subject is the development of handling qualities criteria. These are quantitative, design-related parameters, or measures which define various levels of handling qualities ranging from optimum to minimum acceptable.

The existence of specialized research tools and techniques in this field is due in large part to military needs for comprehensive handling qualities specifications. The essential background information could only be obtained through a broad program of analysis and experiment, and thus the services fostered the development of a large array of simulation facilities, both ground-based and in-flight, and played an important part in the refinement of powerful analytical tools such as pilot/vehicle system analysis.

These are now being used to develop background pertinent to general aviation airplanes.

In the general aviation field, I would like to mention three main criteria-development programs, all of which have taken place in the last decade. FAA sponsored the use of the Princeton Navion in-flight simulator (the blue one which you saw at the Forrestal this noon) in extensive work of this kind. Additional FAA-sponsored work went on at Cornell Aeronautical Laboratory using the T-33 in-flight simulator. The third program was a NASA-funded study at North Carolina State University which drew ride and handling criteria from an analysis of NASA literature. This last effort was one of the efforts which grew out of a plea from industry to make the NASA literature more accessible and to put it in a form that can be easier to use.

I would like to comment here on a few of the in-flight simulators before talking about the experiments more extensively. Just for historical purposes, this is how the blue Navion looked when we first started using it on the FAA programs (Fig. 1a). The mast on the canopy held an angle of attack vane.

Before we were finished with that project, we had done some clean-up work and it evolved into a fairly respectable airplane for a little while. This is how the machine looked when the bulk of the FAA work was done (Fig. 1b). Finally, this the current configuration (Fig. 1c).

The Cornell Aeronautical Laboratory's famous T33 in-flight simulator is one of the real work horses of the trade. In this particular view, (Fig. 2), we have the drag pedals out. This is another side-force airplane, incidentally. They are developing side force in this picture by a large



Fig. 1a

Princeton Navion In-Flight Simulator



Fig. 1b

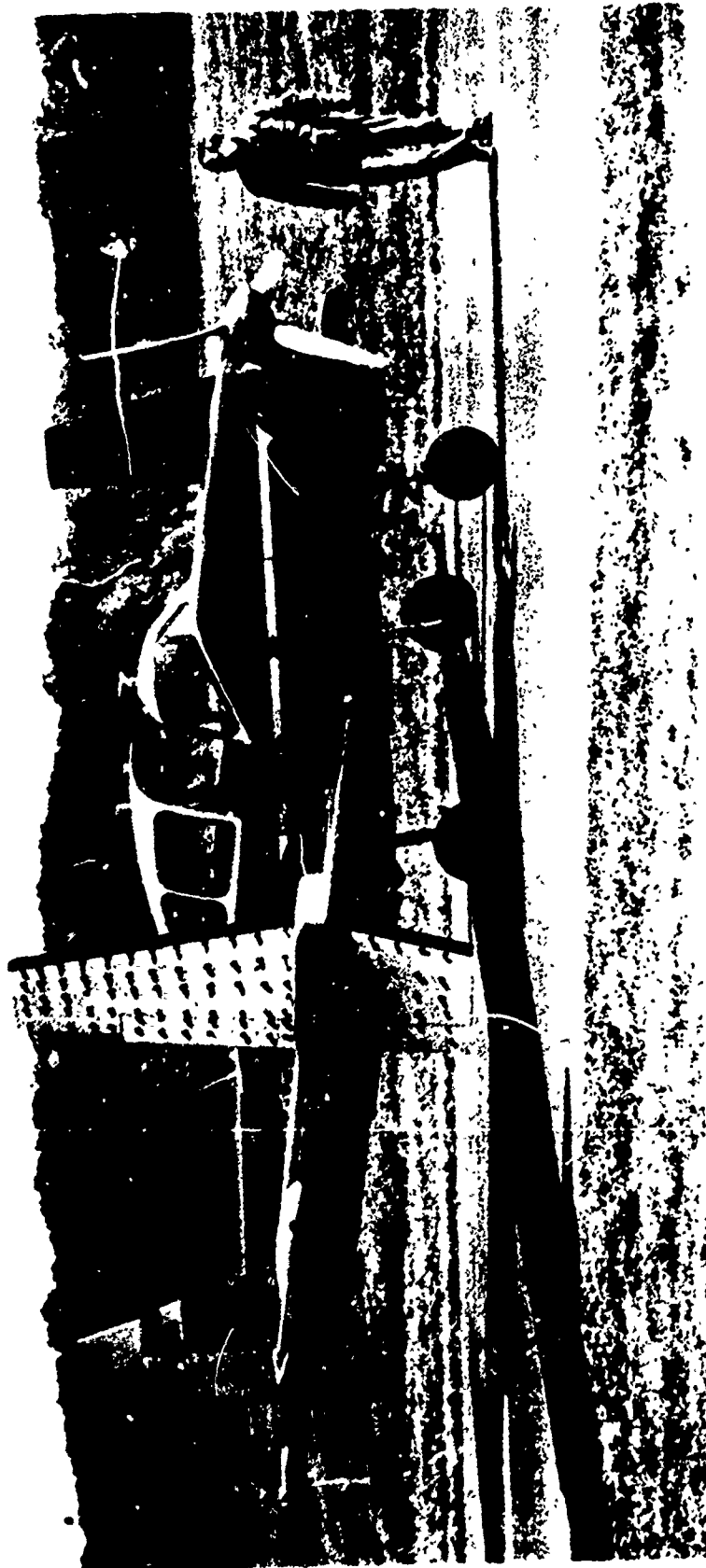


Fig. 1c - Navion Aircraft with Side Force Surfaces Installed

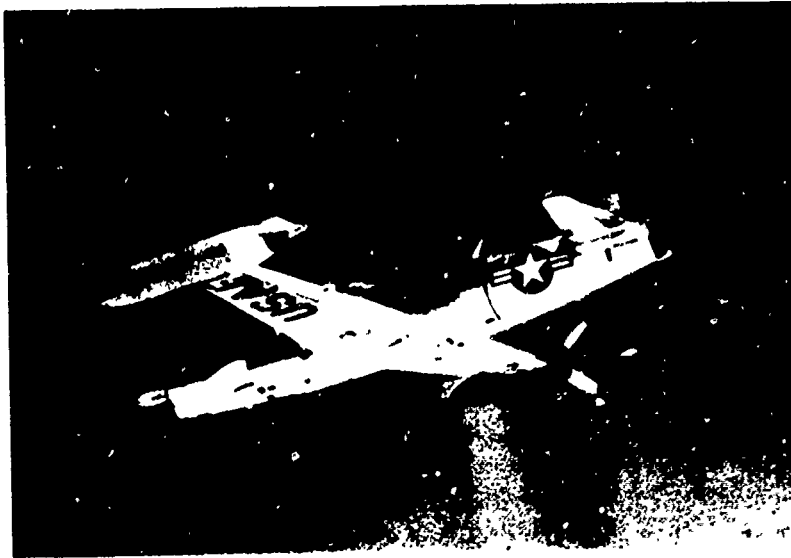


Fig. 2 - Cornell Aero Lab's T-33 In-Flight Simulator

rudder deflection, balancing the yawing moment with asymmetrical operation of the drag pedal. Basically, the in-flight simulators are airplanes with fully powered control systems, with many possible signal inputs in addition to those from the cockpit controls. They are fly-by-wire airplanes. In a little airplane like the Navion, we can literally make it seem to the pilot as though he is flying something like a C-5 or a 747, a medium twin, a fighter. We could even make it handle like a BD5 if we wished.

The basis of the work is a flight experiment in which we can carefully control all or most of the variables such as the atmospheric conditions; the characteristics of the airplane; and the flight phase and the piloting task. Runs are flown on a given task until we have established the most favorable level of a given characteristic and its minimum acceptable level. In any given program, we will usually try to push well away from the good area and into areas which are bad. I would like to point out that we keep everything fixed, if possible, at favorable levels except the parameter of interest. For instance, we can reflect aerodynamic characteristics, inertia characteristics and flight conditions, so that the information is quantitatively useful to the designer.

One could have an airplane which would be impressively stable in smooth air but which would exhibit excessive motions in turbulence, both in roll and in yaw, and thereby would be judged less satisfactory than aircraft with lower levels of directional stability, causing problems for the pilot in maintaining a desired heading. The airplane has a very "loose" feeling in yaw and precise crosswind corrections would be difficult to make. These particular results pertain to an ILS approach in moderate turbulence.

The judgement of what is good or bad is provided by experienced evaluators, usually several of them in any given program. There is a rather formalized way of going about judging flying qualities; Mr. Harper has his name associated with such a rating system. In addition, we try wherever possible to look at other measures besides the qualitative judgement of the pilot, such as airplane motion and control input time histories. All of the available information is correlated in the process of interpreting the results of the experiments.

I won't discuss any more particular results, since reports are available which summarize the recent work in this area. I would like to go on and address the question of where we stand in this matter of criteria definition.

There are some areas which, in my judgement, are adequately defined. This is not to say that we are 100 percent sure of all the details, but I think we have enough of the answer that additional work really isn't warranted at this time. The flight phases that we are fairly confident about are the cruise and landing approach with criteria outlined in the following cases: Stick-fixed longitudinal characteristics; pitch control effectiveness, i.e., the sensitivity of the pitch control, as differentiated from the total control power; most of the roll response characteristics, including roll damping, roll control sensitivity, and adverse yaw. Dutch roll damping has been gone over again and again, and the directional stability and dihedral effect subject is pretty well in hand. Work carried on at Cornell and at Princeton with the variable stability airplanes has probably told us most of what we need to know about necessary levels of spiral stability for all flight phases. With

regard to spiral stability, I might mention that if you obtain it aerodynamically, you will probably pay the penalty of poor gust response. This can be avoided by using one of the wing-leveler concepts.

As criteria which, in my opinion, are poorly defined, we have listed some items which are related mainly to the landing flight phase. One very good reason for this is that, until fairly recent times, we haven't had the experimental tools to do the job. The variable stability airplanes that were available in the 60's - the Navions as they were then, and the T-33 - just weren't suitable for evaluation landings. The airframes weren't strong enough, and their control systems didn't have sufficient safety or redundancy of doing hundreds, or perhaps even thousands of landings seeking answers as to what is good or bad. This situation has changed somewhat, with both Navions now configured and available for landing work.

I would like to discuss these poorly-defined items in turn. In the area of longitudinal stability, criteria are lacking for stick-free characteristics - the characteristics which are measured in terms of control column force versus velocity rather than deflection versus velocity and are strongly affected by gadgetry such as downsprings and bob weights.

In the lateral-directional area, we will include the crosswind factor as well as the landing. First, there is insufficient information to define roll and yaw control power requirements; although you can do approach experiments to try to find limits on controllability, the extrapolation to the actual landing situation is difficult. The problem of allowable roll and yaw control forces enters the picture also. This - the crosswind landing - may be the situation where the largest control deflections are needed, and if you are using a crossed-control technique, you may have to hold large forces for a relatively prolonged period.

Dihedral effect, which we have said we know enough about for the landing approach, should be re-examined for the crosswind landing case. In approach experiments, for example, you find that the level of dihedral can vary over a wide range, including negative dihedral effect; i.e., not the normal sense, without seriously degrading the flying qualities. This may not hold for the landing case.

The next subject is Dutch roll damping. You can accept very low levels of Dutch roll damping in cruise and approach, but this may become more critical for the touchdown case; there is some good evidence that this is so from the results obtained in low passes over the runway. But again, it should be checked with an actual touchdown.

The last item concerning combined poor characteristics has bothered all of the practitioners in the flying qualities field. The way in which we structure experiments usually involves keeping everything favorable except for the one factor under study. No one has yet defined a good experiment in which one bad characteristic is combined with another bad characteristic, finally giving the pilot two or three or four bad qualities to cope with at one time. Or consider a case which is on the borderline between being clearly satisfactory and being slightly deficient. What happens if you put three or four of those characteristics in the same airplane? Does the airplane as a whole slip and become deficient? This is something that needs to be investigated for all flight phases.

There are two major areas which, as a handling qualities researcher, I would like to suggest as suitable focal points for research in the near future. The landing area is one of them. There is a great deal to be known and understood about the basic mechanics of the flare and touchdown in addition to the things mentioned previously in the criteria area. There is research going on now in the particular concept category, one example being the NASA-Langley Slot Spoiler on the Piper PA-24 Commanche which you saw at Forrestal this afternoon (Fig. 3). This is a device which will be investigated for its potential as a direct control over lift during the flare and touchdown. There are additional experiments being run on the NASA-Ames/ARAP Spoiler Musketeer (Fig. 4). Some recently completed, but unreported work with this airplane has been in the area of night landings; another experiment has expended the approach speed/flight path angle envelope to the limits of the present system. The potential of segmented approaches will be explored in the near future.

There is some basic landing research work in process at Princeton. This is NASA-sponsored, using the Red Navion. This a generalized study of the landing process, with the goal of giving the designer the information he needs to produce a good landing airplane by intention rather than by chance.

The other important research area which Frank Castellon mentioned and which Seth Anderson will expand on, is that involving study of stalls and spins. I won't dwell upon it except to note that particular concept work is in progress with the Piper PA30 at Texas A&M (Fig.5). There is some upcoming FAA sponsorship in this area and NASA-Langley has a spin program underway using the Yankee airplane which is on display (Fig. 6).

To sum up then, this is what has been going on for the last ten years. I hope that by having been exposed to it, you can understand some of the reasons for it. And again, I would advance the thought that the landing area and the stall/spin area should be the focal points for research in the next few years.



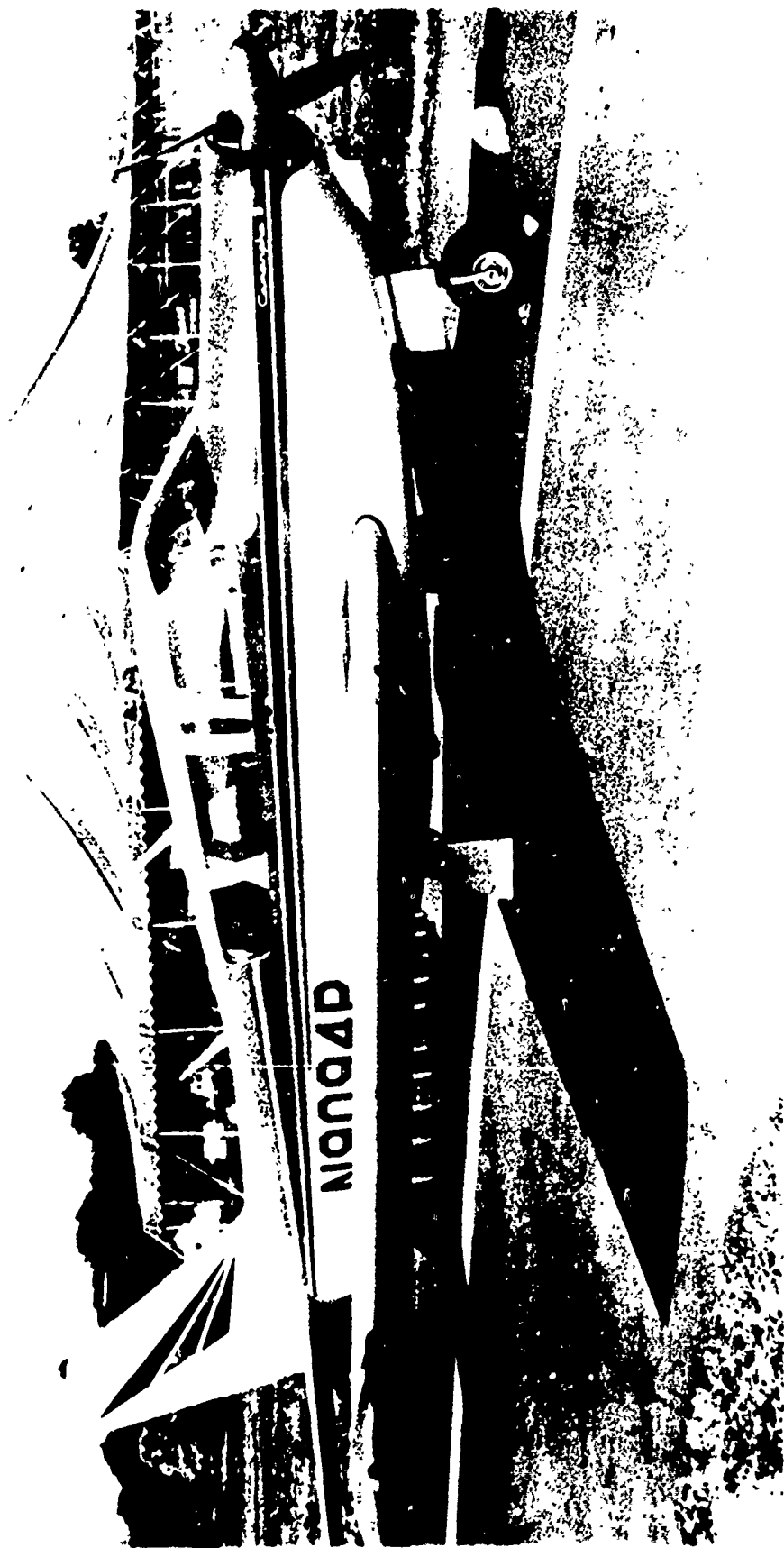


Fig. 3 PA-24 Comanche Used in NASA-Langley Slot Spoiler Research Program



FIG. 4 Spoiler Installation on NASA Ames/ARAP Beech Musketeer



Fig. 5 PA-30 Used in Texas A&M Stall Prevention Research Program  
With Princeton Navions in the Background



Fig. 6 Grumman-American Yankee Used in NASA-Langley Spin Research Program

## Design Considerations for Stall/Spin Avoidance

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### Summary

The paper discusses three aspects of the stall/spin problem: (1) aerodynamic effects, (2) stall warning, and (3) stall limiting. The results show that the stall/spin problem could be alleviated by good handling qualities up to and beyond the stall, careful selection of aerodynamic parameters which promote spin-resistance, adequate stall warning methods and stall margins, and an acceptable form of limiting elevator effectiveness near  $CL_{max}$ .

### Introduction

As noted in a previous paper, stall/spin accidents involving general aviation aircraft have historically accounted for more fatal and serious injuries than any other cause of accident. The classic stall/spin accident is one in which the pilot stalls the aircraft at too low an altitude to effect recovery. This situation usually arises insidiously; the pilot not expecting to stall and out of practice when he does. For example, after engine failure on takeoff, the pilot attempts to turn back to the runway quickly before he runs out of altitude, or, in turning into the final approach leg in a crosswind, he perceives that for his normal bank angle, the turn rate is such that the aircraft will not be lined up with the runway. As a consequence, he banks more steeply, using some bottom rudder to help bring the nose around, simultaneously applying back pressure to avoid dropping below his intended glide path. Suddenly the low-wing drops sharply, and with an unaccustomed close-up view of the ground from a steep nosedown attitude, he instinctively pulls back harder on the elevator control which, of course is in the wrong direction for stall/spin recovery.

In the past, several attempts have been made to design aircraft with special low-speed characteristics to avoid the stall/spin problem, but these approaches have met with only partial success. One early example, the Curtiss Tanager, winner of the Guggenheim Safe Aircraft Competition in 1929 could "fly at any airspeed from 45 to 100 mph at any throttle opening for five minutes in gusty air, hands-off control." This aircraft with a wing loading of 8.5 psf sustained major damage during a slow-flight demonstration and never achieved popularity. The Ercoupe, which in effect was non-stallable, was more popular; however, even this aircraft has been involved in several low-speed crashes. Although these example aircraft were undoubtedly safer to fly at low speeds, there are many reasons why they did not turn out to be the panacea for the stall/spin problem. The purpose of this paper is to review several primary factors which affect stall/spin behavior of general aviation-type aircraft, with a view to obtain a clear understanding of the trade-offs involved in stall/spin avoidance.

This paper covers three factors related to the stall/spin problem. Included are: (1) aerodynamic effects relating to the overall aircraft behavior in terms of the deterioration of several important stability and control parameters at low speeds; (2) stall warning, relating the needs for satisfactory intensity, type, and margin from the stall; and (3) stall limiting, by which high angle of attack operation is prevented by changing elevator pitching-moment effectiveness.

### Results and Discussion

In the typical stall/spin accident examples previously noted, several questions can be raised which reflect on design considerations for stall/spin avoidance. These include: (1) why did the aircraft diverge to reach extreme attitude at the stall and what aerodynamic factors promoted the tendency to spin? (2) was stall warning present and if so, was it at the correct margin from the stall and in a form to motivate the pilot to release back pressure on the elevator control and avoid the complete stall? and (3) what are possible design features or modifications to the aircraft which would prevent entry into the stall region? In the following discussion factors related to these questions will be addressed.

### Aerodynamic Considerations

One may ask whether it is possible to design a General Aviation-type aircraft with built-in aerodynamics that provide such good low-speed handling that even the novice pilot would not get into a stall/spin problem. In particular from the manufacturer's viewpoint, can the aircraft be made inherently spin-resistant without special gadgetry and without undue compromises in overall performance, appearance and cost? This is a difficult question to answer because of the interrelated effects of many parameters which affect stall/spin behavior. This portion of the paper discusses the effect of basic aerodynamic characteristics on the stall/spin problem. Attention will be directed to the parameters affecting the stall/spin entry and will not treat spin recovery aspects, since this is a tremendously complex problem in itself and is beyond the scope of this paper. Even the stall/spin entry is very complex; however, it is hoped that the following discussion will help focus attention on possible solutions to the problem.

Identification of parameters - Stall/spin behavior of an aircraft is related primarily to the following aerodynamic parameters:

- o Life curve  $\text{top}$ ,  $C_L$  versus  $\alpha$
- o Rolling moment,  $C_l$
- o Roll damping,  $C_{l_p}$
- o Roll control power,  $C_{l_{\delta_a}}$

- o Aileron adverse yaw,  $C_{N\delta_a}$
- o Directional stability,  $C_{N\beta}$
- o Yaw damping,  $C_{N_r}$
- o Dihedral effect,  $C_{l\beta}$
- o Side force  $C_Y$  and yawing moment
- o Yawing moment due to rolling,  $C_{N_p}$
- o Pitching moment,  $C_m$

As can be observed, this is a formidable list of items, and it will be possible to discuss only a few of the most important ones at this time. It may be noted that nonaerodynamic factors which strongly influence spin characteristics, such as inertia distribution, are not included in this listing.

The variation of lift coefficient with angle of attack near maximum lift (shape of the lift curve top) is one of the most important design considerations for low-speed flight because it directly reflects the potential seriousness of the stall/spin problem. A sharp lift curve top, that is, one where lift decreases rapidly due to large areas of airflow separation, usually results in a large bank angle (roll-off) at the stall. This is illustrated by the data of Figure 1, which show lift and rolling moment variations measured in the NASA-Ames full-scale wind tunnel for an aircraft with two wing leading-edge configurations. Note the relatively large roll-off for the cambered leading edge which in this case was designed for high speed considerations. Note also that the large rolling moment occurs over a very small angle-of-attack range which is due to an asymmetric breakdown (stalling) of the airflow, initially over one wing panel. How this roll-off can degenerate into the forces which cause a spin is illustrated in Figure 2. In the roll-off, the down-going wing experiences a larger angle of attack with a lower lift and also a very significant higher drag, while the opposite is true for the up-going wing; this setting up the autorotation forces which sustain the spin motion.

In answering the question of what can be done in the aerodynamic design of an aircraft to preclude the tendency to spin, the first obvious answer is to make it impossible to stall the wing by limiting the pitch control power to less than that needed to trim at angles of attack near stall. As discussed later, this may have possible disadvantages by restricting maneuvering (less "g" available) and still leaves open the possibility of inadvertently stalling in gusty air. The next step is to design for a gentle stall, with initial airflow breakdown disposed symmetrically at the wing center section. This action lessens the tendency to roll-off at the stall and because of the reduction of downwash at the tail, the aircraft will tend to pitch down out of the stall region. This good stall pattern is accomplished by judicious selection of airfoil sections, proper combinations of wing thickness, twist, taper ratio, etc. To provide the gentle, straight-ahead stall for all combinations of flap, gear, engine power, and without unduly degrading high-speed performance is admittedly not an easy task, but enough technological

base is available in the literature for the designer to achieve this goal. Unfortunately, although the gentle stall is certainly a most desirable feature, it in itself will not completely solve the stall/spin accident problem, since we know the simple J-3 Cub has a good, gentle stall, but a bad stall/spin accident record. Let us next examine other aerodynamic factors which promote the spin tendency.

Shown in Figure 3 are typical variations with  $\alpha$  of several aerodynamic rotary derivatives that have a pronounced effect on the spin tendency. Note that these parameters change sign at the stall and remain unstable at high angles of attack which tends to promote spinning. An unstable break in pitching moment will cause the aircraft to inadvertently enter the stall region in an uncontrolled manner. Of the various parameters shown, one of the more important is directional stability,  $C_{N_\beta}$ , since a reduction in its stabilizing function at high values of  $\alpha$  allows yaw excursions to build up to a high enough rate where autorotative forces can predominate. This is true also for roll damping since there is no resisting force to reduce the roll rate. The change in dihedral effect,  $C_{l_\beta}$ , is also significant, since at the high  $\alpha$ 's the self-righting tendency to raise the low wing by sideslipping may be nonexistent. The consideration of directional stability about the stability axes or flight path is called  $C_{N_\beta}$  dynamic and is defined by the following equation:

$$C_{N_\beta \text{ DYN}} = C_{N_\beta} \cos \alpha - I_z/I_x C_{l_\beta} \sin \alpha$$

where  $I_z/I_x$  is the ratio of the yaw to roll moments of inertia. Studies have shown the influence of  $C_{N_\beta \text{ DYN}}$  on the spin tendency to be very powerful. In fact, it has been documented for military aircraft that with the proper (stable) combination of  $C_{N_\beta}$  and  $C_{l_\beta}$  with angle of attack it is virtually impossible to promote a spin with normal control usage. Providing directional stability out to angles of attack beyond the stall is, unfortunately, very difficult, particularly when it is desirable to locate the tail in the stalled wing wake. Nevertheless, it has been achieved on some military aircraft and more work needs to be done on general aviation configurations to achieve this goal. Finally and equally important are the aileron control characteristics, since large amounts of adverse yaw due to aileron deflection,  $C_{N_{\delta a}}$ , tend to promote spin entry when the ailerons are used to prevent roll-off at the stall. In spite of the continued emphasis given in pilot training to use only the rudder to raise the low wing at the stall, pilots will instinctively use aileron in a stressful situation. Fortunately, there are a number of lateral control schemes known to the designer which can provide good lateral control at the stall with low values of  $C_{N_{\delta a}}$ .

In summarizing at this point, the design philosophy simply stated to alleviate the stall/spin problem is two-fold: (1) provide good handling qualities up to and beyond maximum lift, and (2) make the aircraft spin-resistant. The first item requires that the design features provide stable static and dynamic stability characteristics with good control about pitch, roll and yaw axes. The second item requires the designer to know how to achieve stable contributions of several aerodynamic rotary derivatives out to large angles of attack. The ability to accurately predict aircraft behavior at the stall and beyond obviously needs improvements for general aviation aircraft. Experience has shown the aerodynamic factors which influence stall/



spin behavior may be nonlinear and dependent on interference effects as well as being configuration-oriented. In addition, reliable wind tunnel data of rotary derivatives out to high angle of attack required specialized test equipment and Reynolds Number effects are always questionable. Because of these complexities, the NASA-Langley Research Center has started model tests of typical general aviation configurations using four techniques: (1) wind-tunnel, free-flight, (2) outdoor, radio-controlled model, (3) spin-tunnel test and (4) aircraft flight test. A description of the scope of this program is given in Ref. 1. It is expected that after establishing the technology base for general aviation aircraft in the stall/spin regime, studies will be made to determine how to achieve the stable variations of the aerodynamics parameters previously discussed out to large angles of attack.

At this time, it is not known if a satisfactory solution to the stall/spin problem can be achieved for general aviation aircraft by means of the correct combinations of basic aerodynamics. More research is needed particularly to assess the trade-offs so that the manufacturer's desire for high performance good looks and low cost can be retained to the greatest degree. Assuming at this point that some improvements in aerodynamics can be made, a further step to reduce the number of stall/spin accidents is to convincingly warn the pilot that evasive action must be taken in time to prevent the stall. This warning aspect is discussed next.

#### Stall Warning Considerations

Type of warning - The need for some form of stall warning has long been recognized as an essential element to provide safe operation near the low-speed end of the flight envelope. It has generally been established that the approach to the stall should be marked by one or more of the following:

- o buffeting and shaking of the aircraft and controls
- o marked increase in rearward control travel or increase control for further speed reductions
- o small amplitude (non-divergent) pitching and/or rolling motions

Of these, the first is most desirable because it is difficult to ignore, and if the buffet magnitude increases as speed is reduced, it is more provocative than other forms of warning, and, of course, has inherent reliability. Unfortunately, achieving the correct magnitude of buffeting at the proper margin from the stall and for all flight conditions, flap settings, engine power, etc., is not easy to accomplish, particularly in the preliminary design stage. During the flight test development program to improve stall warning, stall strips are sometimes added to the wing leading edge. Without the benefit of good analytical prediction techniques and/or wind tunnel tests, however, the size and location of the strips chordwise and spanwise on the wing to produce airflow breakdown at the proper speed (and load factor) is more an art than a science. Because of all these factors, artificial stall warning devices of aural and tactile nature are commonplace on many general aviation aircraft. The success of these devices depends on initiating the warning at the correct margin from the stall and, of course, their effect must motivate the pilot to avoid the stall. These factors are discussed next.

Stall warning margins - Systematic studies to determine stall warning margins for general aviation aircraft have not been pursued in depth in recent years; and speed margin criteria established quite a long time ago (Ref. 2), which formed the basis for the criteria used in MIL Spec. 8785, have also been adapted for civil use in FAR Part 23. Shown in Figure 4 is a correlation of pilot opinion with stall warning margins and buffet (normal acceleration change) taken from Ref. 2. Judgement of whether or not the stall warning is satisfactory is dependent not only on the initial amplitude of aircraft buffet, but also on the speed above stall where buffet first begins and then on how rapidly buffet increases with decreasing airspeed. The boundaries shown on the figure were established as follows: An upper limit of buffet intensity was needed because of the pilot's concern for structural integrity of the aircraft. The boundary for the lowest speed above the stall where the pilot would accept buffeting as a satisfactory stall warning is somewhat difficult to firmly establish due to the interaction of several factors. These include, among others, the influence of the magnitude of buffet at the onset and the aircraft behavior in the complete stall. In general, less speed margin is needed if buffet is more intense at the onset, and also a stronger intensity is required when the stall behavior (roll-off) is more severe. A region too far on the right did not serve as satisfactory stall warning for several reasons. At speeds in excess of approximately 10 knots above the stall, the buffeting was too far removed from the actual stall to adequately serve as a warning of the complete stall. Another unsatisfactory aspect of the early buffet is that the magnitude usually builds up as the stall is approached, such that the pilot may be concerned about structural fatigue damage to the aircraft. Of course, large amplitude buffeting over a long period before the stall would be particularly objectionable in landing.

In the foregoing discussion, we have examined stall warning criteria during gradual approaches to the stall. What happens to the requirements for stall warning during rapid pull-ups or in accelerated turns? One factor, time margin ( $\Delta T$ ), which is the amount of time in seconds between warning onset and maximum lift ( $C_{L_{max}}$ ) becomes significant, particularly for some types of artificial warning devices. In a recent unpublished FAA flight study of representative artificial stall warning systems, the significance of the time margin was brought out. Typical results from these tests are presented in Figure 5. Note that the warning time decreases rapidly to a more steady value as the approach to the stall is made more abrupt. At present, the stall demonstration guidelines in FAR 23 require that the speed reduction rate during the approach to the wings-level stall not exceed one knot per second. Considering also that the allowable speed margin is from 5 to 10 knots, the  $\Delta T$  before stall can be as long as 10 seconds. This could possibly lead a pilot into a false sense of security about proximity to the stall. If he thought he always had 10 seconds to do something to avoid the actual stall, he could stall inadvertently during a rapid pull-up or an accelerated turn where  $\Delta T$  could be only a few seconds. The consensus of this FAA study is that a time margin and speed margin may both be required and that the warning device should provide a constant warning time of approximately 3 seconds regardless of the approach rate to the stall.

Summary remarks on stall warning - If one asks how effective good stall warning is for stall/spin avoidance, the answer would be that it helps, but in itself is not the complete solution to the stall/spin problem. To be truly effective, the warning must motivate the pilot to instinctively apply corrective action to avoid the stall. An aural stall warning is an example of a device that can easily be ignored, and there is nothing inherent in its sound that commands the correct control action for stall avoidance. Even aircraft buffeting, although perhaps the easiest to interpret and certainly the most reliable, can be ignored during a rapid approach to the stall particularly in gusty air. What is really needed in addition to providing good stall warning is a better pilot appreciation and awareness of the abnormal flight condition. The pilot who will ignore the signs of stall warning and allow a high rate of sink to develop at low airspeed seems doomed for disaster. Perhaps the only solution is to prevent him from reaching the low speed part of the flight envelope. Considerations for this type of stall/spin avoidance method are discussed next.

### Stall Limiting Considerations

Because the pilot may be preoccupied with a stressful situation and because in some cases the consequences of stalling may be unusually severe, some means for limiting the capability of the pilot to reach  $C_{Lmax}$  may offer the only possible cure to the stall/spin problem. By actually restricting the angle-of-attack available to the pilot, the airflow over the wing will always remain attached with less deterioration in low-speed handling qualities. An early example of stall limiting was incorporated in the Ercoupe, the most successful "safety plane" in the General Aviation category. The Ercoupe was made "stall-proof" by physically restricting elevator control column travel. More recently, stick pushers have appeared, particularly in aircraft which have serious "deep stall" problems. The stick pusher applies a nose-down pitching moment at some preselected angle of attack near stall. Because of its complexity, cost, and fail-safe aspects, it has not achieved wide application in General Aviation aircraft, and will not be discussed in this paper. The following discussion reviews the relative merits of other stall limiting methods.

Effect of limiting elevator travel - The most straightforward method of preventing stall is to restrict elevator travel such that insufficient pitching moment is available to trim at maximum lift. This is illustrated in aerodynamic terms in Figure 6. Shown are the associated lift and pitching moment variations with elevator travel limited so that it is not possible to attain zero (trim) pitching moment at high angles of attack. In practice, a margin must be maintained to prevent dynamic overshoots into the stall area. As with any design, there are several trade-offs which include: (1) the CG must be controlled so that passengers and fuel load do not affect trim; (2) trim changes due to engine power and flap and gear setting must be minimized; (3) there may be insufficient tail moment for maneuvering at low angles of attack and, therefore load factor may be restricted; and (4) one must be content not to be able to make a "full stall" landing - not too difficult a problem for modern tricycle gear aircraft.

Although the principle is simple from an aerodynamic standpoint, one has to admit that this method has not gained great popularity even on aircraft restricted to the Ercoupe class. It is possible, of course, to zoom-climb the Ercoupe to a high enough pitch attitude where recovery may be questionable when performed at low altitude. In fact, NTSB records show that 13 Ercoupes suffered stall/spin accidents in the 1967-69 period, although it is not known if these aircraft had the original control system.

Effect of reducing elevator control effectiveness - Another method of restricting the angle of attack range to that below stall is to limit the amount of horizontal tail lift available at angles of attack near the stall. As previously noted and referring again to Figure 6, when tail lift is limited by restricting elevator travel, there may be insufficient pitching moment for desired maneuvering at low angles of attack. However, if available pitching moment is made to vary as a function of angle of attack so that excess tail lift approaches zero at some angle of attack just below stall, full tail lift would be available for all other flight conditions. This method has been explored at Texas A&M University on a Piper PA-18 aircraft (Ref. 3), and makes use of an aerodynamic spoiler located on the under surface of the horizontal stabilizer. A sketch of the complete spoiler system is shown in Figure 7. Note that angle of attack is sensed at the wing leading edge, and the resolver output causes the actuator motor to deploy the spoiler by an amount proportional to the sensor vane deflection. The optimum size and location of the spoilers were determined by the cut and try method. The spoilers were spring-loaded in the retracted position as a safety precaution.

Tests of this system showed that when the aircraft's speed range was restricted in straight flight to a speed approximately 5 mph above the stall speed (50 mph); the airspeed remained at 55 mph even when additional elevator pull forces were exerted. Figure 8 illustrates typical variations of elevator deflection and control force with indicated airspeed. Note the rapid increase in both elevator and force gradient with airspeed as the stall is approached due to the spoiler disturbing the airflow on the underside of the elevator surface. Similarly, attempts to stall the aircraft in turning flight resulted in a minimum attainable airspeed some 5 mph above the stall speed. Although the spoiler system operates automatically and is therefore independent of the pilot's reactions, he is made aware of the proximity to the stall by the marked increase in stick force and stick travel.

The reduced effectiveness concept unquestionably has advantages over the restricted elevator travel system, and it would appear that applications to higher performance aircraft, including flying-tail types, can be made to work from the aerodynamic standpoint. There may be other methods to accomplish the reduction in elevator effectiveness, such as using a geared elevator trim tab, and more research is underway at Texas A&M. It remains to be seen, however, if this concept will be incorporated on general aviation aircraft in a cost-effective manner without unduly compromising the operational flight envelope. For example, (1) the inability to make full stall landings on some types of aircraft must be more fully assessed; (2) the influence of ground effect on operation of this concept remains questionable for some configurations, and (3) the correct speed (and angle of attack) margins must be explored for different configurations to establish overshoot limits and to account for effects of gusty air and wind shears. Finally, it must show significant reductions in the stall/spin accident rate before its true effectiveness can be measured.

## Conclusions

An examination of the design considerations for stall/spin avoidance for general aviation aircraft has led to the following conclusions:

1. The primary aerodynamic factors contributing to the stall/spin problem are the large rolling and yawing moments at the stall, poor lateral control characteristics, and loss of directional stability at high angles of attack.
2. The stall/spin problem is difficult to solve by aerodynamic means alone; however, design features which provide stable static and dynamic stability characteristics, good control about pitch, roll, and yaw axes, and stabilizing values of several key aerodynamic parameters out to high angles of attack will alleviate the problem to a large degree.
3. Good stall warning characteristics in a natural form with adequate margins from the stall can help motivate the pilot to apply corrective control to avoid the stall/spin area.
4. Solutions to the stall/spin problem by preventing attainment of a stalled condition show that stall limiting by restricting elevator travel has limited application. The method by which elevator effectiveness is reduced only at angles of attack near stall shows considerable promise.
5. A large improvement in the stall/spin accident record could undoubtedly be made by combining the best known aerodynamic techniques to provide a gentle stall and the correct combinations of rotary derivatives to promote spin resistance, good stall warning, and a form of stall limiting.
6. There is a lack of aerodynamic data for the stall/spin regime for present-day light, general aviation aircraft. NASA has started a research effort to obtain a better understanding of the stall/spin problem for general aviation aircraft.

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2. Seth B. Anderson: Correlation of Pilot Opinion of Stall Warning with Flight Measurements of Various Factors which Produce the Warning. NACA TN No. 1968. April 1949.
3. Howard Chevalier and Joseph C. Brusse: A Stall/Spin Prevention Device for General-Aviation Aircraft, Texas A&M University. SAE Business Aircraft Meeting. Wichita, Kansas. April 3-6, 1973.

### Figure Legends

- Figure 1      Lift and rolling moment characteristics.
- Figure 2      Lift and drag characteristics.
- Figure 3      Typical variation of aerodynamic parameters through stall.
- Figure 4      Stall warning boundaries.
- Figure 5      Typical stall warning margins using artificial devices.
- Figure 6      Lift-pitch moment characteristics.
- Figure 7      System for providing reduced  $\delta_e$  effectiveness at high  $\alpha$  .
- Figure 8      Elevator force and position gradient characteristics with stall limiting system.

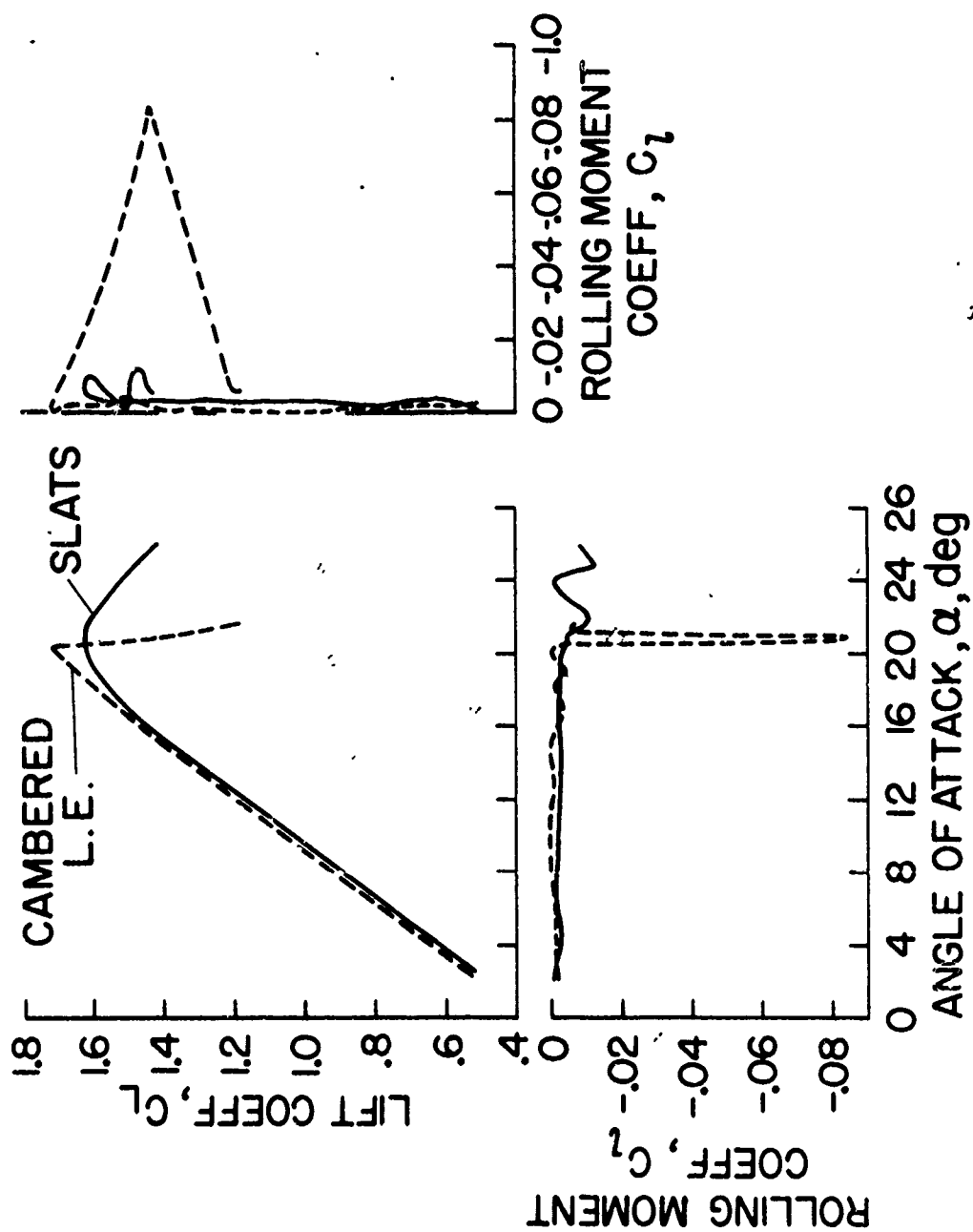


Fig. 1

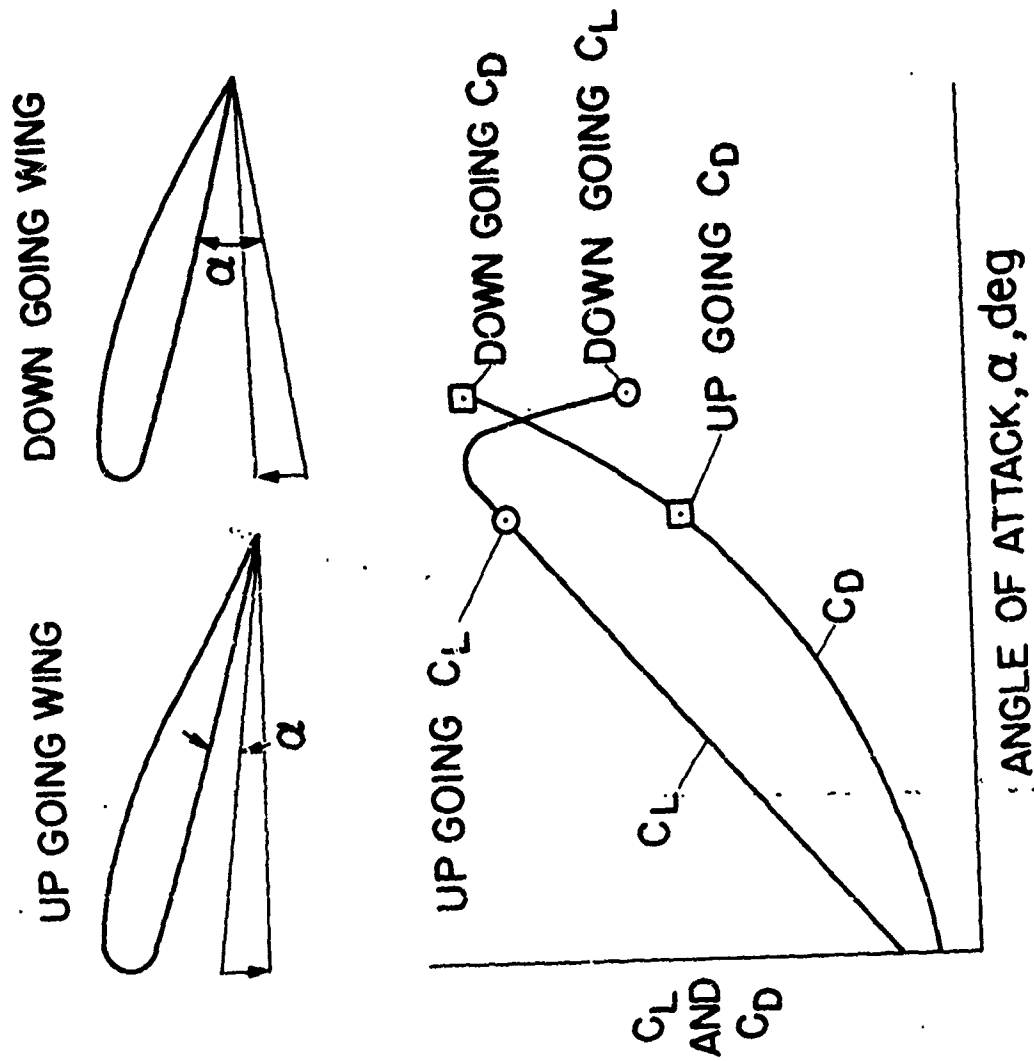


Fig. 2



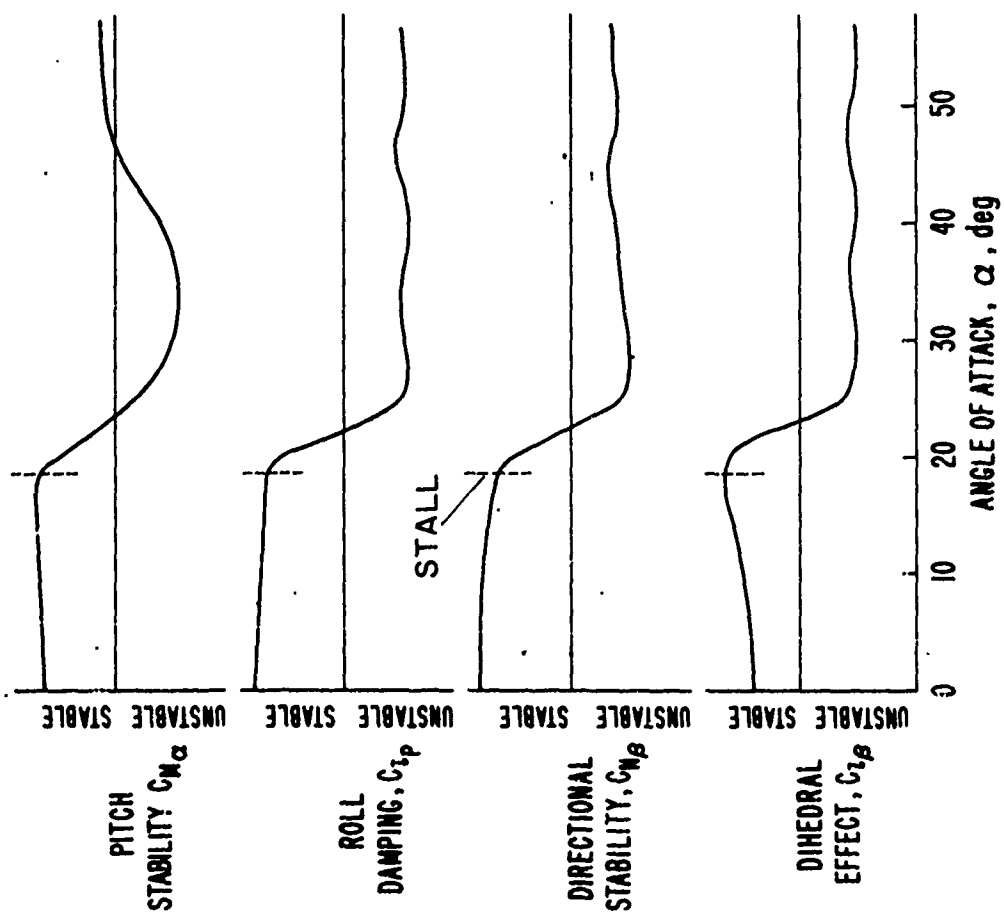


Fig. 3

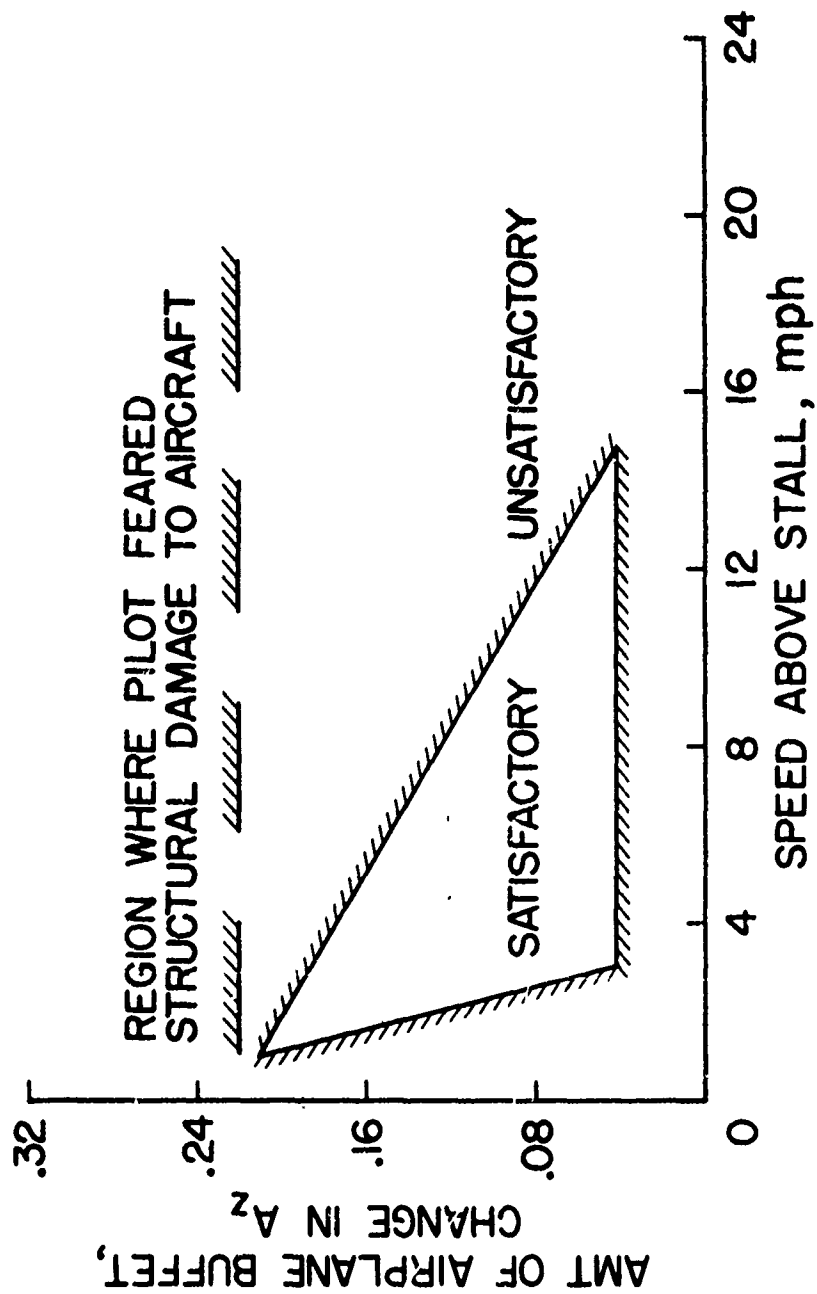


Fig. 4

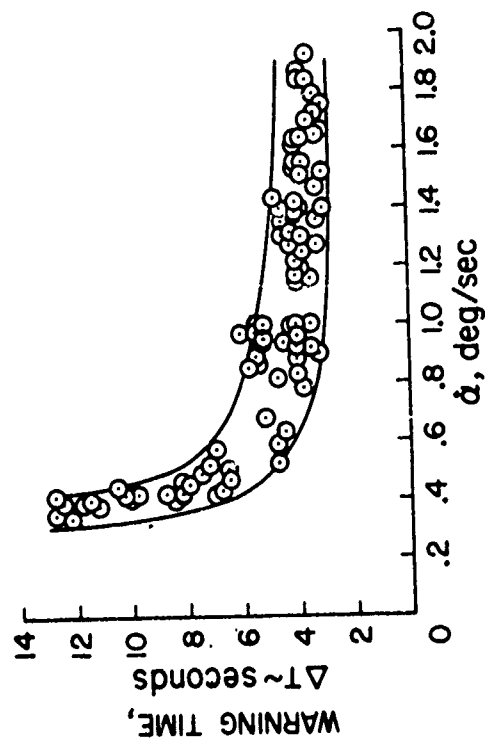
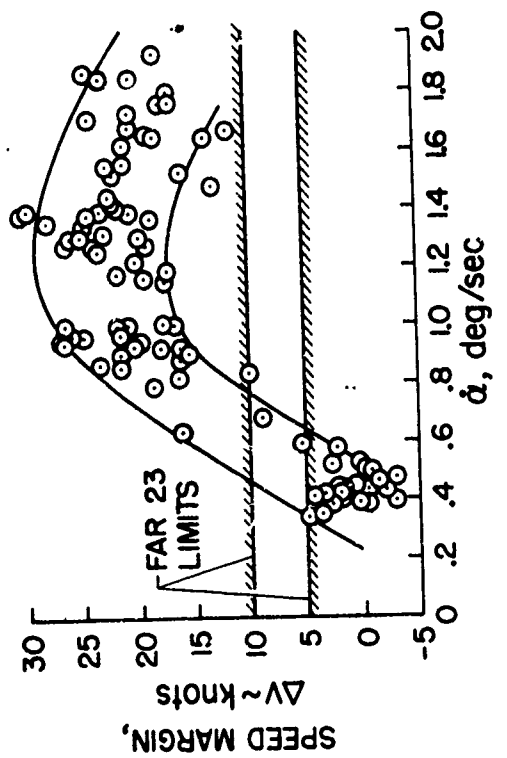


Fig. 5

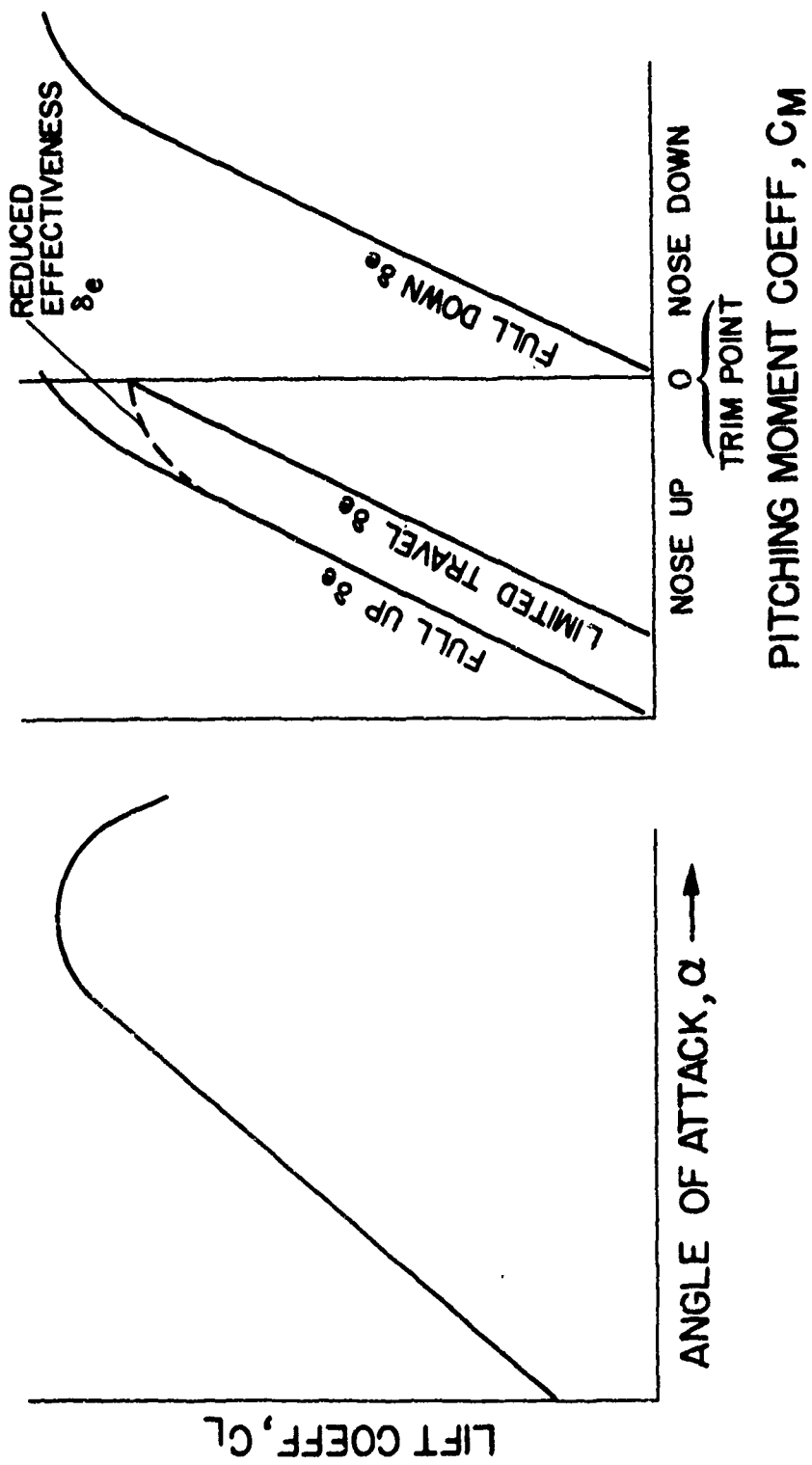


Fig. 6

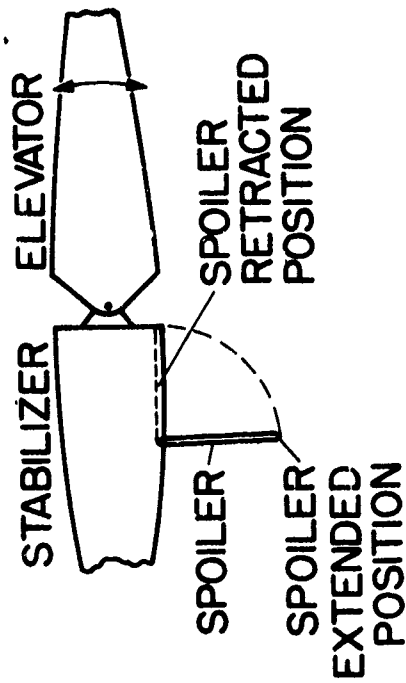
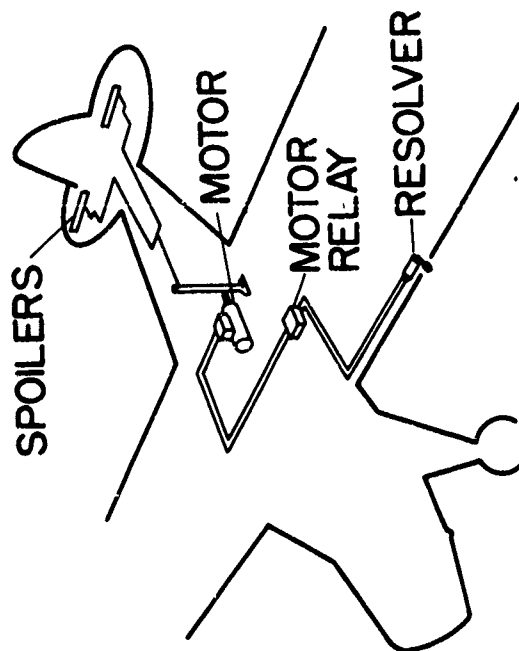


Fig. 7

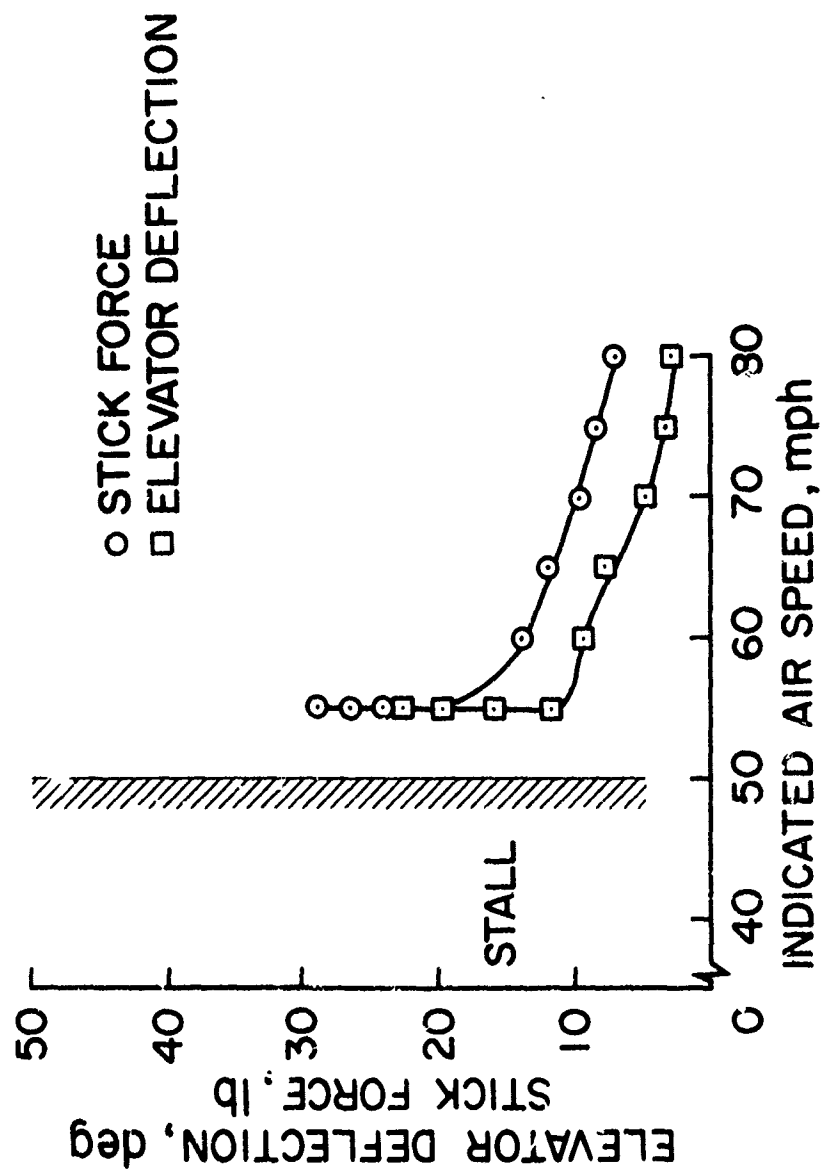


Fig. 8

**DISCUSSION - SESSION II**

**GENERAL AVIATION DESIGN AND SAFETY R & D OVERVIEWS**

Robert P. Harper  
Deputy Head, Flight Research Department  
Calspan Corporation

The really important thing to me as an individual is to hear from this audience, because this is the first time that I have had the opportunity as a handling qualities researcher to have this kind of an audience fire questions about our research business and what it means particularly to general aviation. I think this conference is a very valuable thing and I have the utmost respect for Jerome Teplitz to whom I have attributed the weather prediction capability that Mr. Eggspuehler said we ought to have. I would like to think that a forum such as this in which the research community and the Government and the using community get the opportunity to communicate ought to be held on some kind of fairly regular basis, especially with this kind of start.

I am not very knowledgeable in the crash survivability area. I enjoyed that commentary on the program that the FAA is undertaking a very worthwhile thing. As a general aviation pilot, I can remember trying to put a shoulder harness in an aircoupe and I couldn't find the structure to attach it to. I tried to put a shoulder harness in a Piper Pacer, the o'd tail sitter variety and I was fortunate that the wing was sitting up there and gave me a place to attach it. I think we have needed shoulder harnesses in airplanes ever since we have been flying them. It sure disappoints me to see the automobile manufacturers getting ahead of us. So I don't think we have to solve every problem before we start putting shoulder harnesses in our airplanes. If you can make airline passengers buckle up before the pilot takes off, I don't think we should worry about whether the people who ride in those airplanes are willing to buckle up. It can be done.

Dave Ellis, I enjoyed very much your flying demonstration and I thought that was just beautiful to see one airplane going around in a turn without banking and the other airplane with his wings stuck up. At Calspan, we have fooled around with these side force producing airplanes for a while and I never saw such a graphic illustration of what side force really does. That was quite a demonstration. I am very pleased as a pilot, as an engineer, as a taxpayer to see that finally in this country we are doing some real research in general aviation handling qualities. I have made my living as an engineer mostly doing military oriented research and all during that time flying in part general aviation airplanes and wishing that we as a nation would get busy and start doing something about some of our problems with our general aviation airplanes. That doesn't mean that the general aviation airplanes are bad. It just says there is enough knowledge around to make them better and let's make them better in such a way that they have more utility and also so that they don't kill mamas and kids. I think that is the most tragic thing that I see in the newspapers and accident records is where dad is out flying for a vacation trip or a business trip where he



takes mom and the kids along and he kills them all. Now that is ridiculous. Everybody here knows it is ridiculous. So what are we going to do about it? We have heard a lot of things from Dave Ellis and Seth Anderson about the role of flying qualities, the things that we might do, stall characteristics wise, to improve these airplanes. I think the challenge is that we are not airplane designers. Maybe that is part of the problem, we don't understand enough about designing airplanes. So will the airplane designers in the audience please get up and tell us how we can get this information into better airplanes, better pilots, and then how do we get the needs of the airplane designer back into the research business? I wish we could talk to the designers so that the things that we did were more practical. I think we need to communicate more and more and that is why I think this conference is a very fine thing and I hope we have more of them.

One small comment on Dave Ellis' paper that I think is worth saying is one of the reasons that we in the handling qualities business are concerned with handling qualities in defining what are minimum acceptable levels for handling qualities parameters. I think one of the reasons that we want to build as good handling qualities into an airplane as possible is because airplanes with good handling qualities are less susceptible to errors on the part of the pilot. If they are more forgiving, then those of us who on occasion have to fly without as much training or proficiency or currency as we would like, we are in better shape, we think, with better handling qualities. If you give us problems in the airplane and we are not current and trained in that airplane, then there is more risk of our having an accident.

The lady in the audience who indicated that there was perhaps some inverse correlation between bad handling characteristics and improved performance on the part of the pilot, I think that derives from the training that you get from having to cope and deal with poor handling qualities, but I don't think that can ever be an argument for having bad characteristics in the airplane and I think it is up to us to identify those characteristics which are contributory to our accidents and to undertake some specific programs to improve our airplanes.

In a sense, I ask you as an audience to comment to the panel regarding the subject and what are we going to do with this information? What does all this mean? How do we get it into the business of building airplanes? We mentioned product liability. Is product liability preventing us from building safe airplanes? I hope not.

I have a comment here. The NASA evaluation was no surprise to the manufacturers. The deficiencies that were identified in the flight research center evaluation of the general aviation airplanes were no surprise to the manufacturers. I heard earlier here today that these deficiencies that we have in our airplanes go on and on and on. Statistical correlations show that accidents derive primarily from some shortcoming in the airplane and yet it persists for six and seven years. To the FAA people I say, how does this happen? What do we do about it, we as a group, collectively, we don't want this to go on.

I would like to make a small plea for something I have heard repeatedly today and that is for more research on the role of the pilot in the accident. I think I saw on the slide earlier this morning that 85 or 86 percent of the

takes mom and the kids along and he kills them all. Now that is ridiculous. Everybody here knows it is ridiculous. So what are we going to do about it? We have heard a lot of things from Dave Ellis and Seth Anderson about the role of flying qualities, the things that we might do, stall characteristics wise, to improve these airplanes. I think the challenge is that we are not airplane designers. Maybe that is part of the problem, we don't understand enough about designing airplanes. So will the airplane designers in the audience please get up and tell us how we can get this information into better airplanes, better pilots, and then how do we get the needs of the airplane designer back into the research business? I wish we could talk to the designers so that the things that we did were more practical. I think we need to communicate more and more and that is why I think this conference is a very fine thing and I hope we have more of them.

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I would like to make a small plea for something I have heard repeatedly today and that is for more research on the role of the pilot in the accident. I think I saw on the slide earlier this morning that 85 or 86 percent of the

accidents were attributed to pilot error and I think we all here know what is meant by that, that the pilot involvement was a dominant thing in 85 percent of the accidents that were analyzed. I haven't heard very much about what the problem is. What is it that we do as pilots that cause accidents? We heard that the pilots generally don't know the accident is going to happen until just before it happens. So it says that we as pilots are led into a situation that we are not even aware of until it is really too late.

I think we need some fundamental research and I don't mean research by psychologists or human factors engineers. I mean research by people such as we have heard from today as to what the role of the pilot is in the accident and how he gets involved in this situation. You can't really do this on a bright blue day when the pilot knows that the safety pilot can press a button and take over. What do we do about this? I don't know. Do we build an in-flight simulator, for example, that you can do stall research on? That you can fly an airplane into a simulated stall and be able to press a button and recover? How do you get the pilot in the frame of mind to behave as he does in this panicked situation where he is about to have an accident? I solicit the comments and ideas that this audience may have in this regard.

I would like to go back to the comment in the very beginning as to how do we get youth and innovation into this business. I hope we have it now and I hope we have more of it in the future. I would like to say that I think we have a lot of youth in one segment of this business and that is in the flight training business. They are the only ones that can live on a flight instructor's salary. I don't think that is all bad. I was talking to Fred Rowley from Grumman and he remarked to me today that it is kind of hard to reflect back to when you were learning to fly and what your problems were. I think our youth who are flight instructors now are close enough to the problems of learning to fly that if we do something with their enthusiasm and their youth, if we employ it to our own advantage, I think we will come out well ahead. I don't think we have to pay our flight instructors three or four times what we currently do. I think we have to figure out how to use the youth that are soaking up those jobs right now. Maybe we need a professional corps of flight instructors who essentially monitor the flight instruction across the country. I heard today about the Ohio State University curriculum and it sounded tremendous to me, but how many airports in this country do you think you can go to and get that kind of instruction? Yet every one of them is selling instruction.

Have we done a correlation of the accidents that have happened with the source of the instruction that they have received? We have heard that people who have accidents are bad credit risks. Where did they get their flight instruction? Perhaps we can incorporate professionalism into flight instruction through some monitoring system or national flight school that provides some overseeing of the way we conduct flight training in this country.

Two more comments. One is that I don't think the accident rate is quite as bad as it appears. The fact that we are having very little improvement in our fatalities is somewhat obscured by the fact that we are using our airplanes a lot better and using them in more difficult tasks. I think if we hadn't made improvements in our flight safety and in our instruction, etc., that

we would be experiencing a significant rise in the fatalities. I somehow have the feeling that the multi-engine accident rate for example, is in part due to the fact that people who fly those airplanes are using them more extensively at night and in IFR conditions than people who are flying the single engine airplanes a lot of the time around the airport.

One final plea. This is just a pet thing that I have felt for a long time. I have a military background. I first learned to fly as a civilian and then I went through the military training program and I flew for a number of years on active duty and then in the reserve program. When you are in the military, the thing that the pilot lives with is the pilot's handbook on the airplane he flies and I think that the pilot handbooks in this general aviation industry are a sin. Not all of them are equally bad, but they are all bad and worse still, even if they were good when the airplane came out they are not kept up. So I ask the FAA and would like the comments if possible, are you doing anything to provide the pilots of this country with a up-to-date handbook? When there is an accident in a certain class of airplane that they keep up the books on, one wonders if it is due to the change in the fuel valve operation and the way it should point when the tank is on. Are the guys advised that this is the way it is? Pilots love flying or they wouldn't do it. It costs too much. It requires too much attention and training. There is a lot of motivation. They will read almost anything. The people from Flying Magazine, Air Facts know they have a good circulation and we who are the enthusiasts wait to see what they have to say every month. We are dying for information, but we don't get it on our airplanes. What are we going to do about that?

Karl H. Bergey  
Professor, Department of Aerospace, Mechanical and  
Nuclear Engineering  
University of Oklahoma

I am somewhat disturbed by some of the things I think I heard today and in particular the emphasis on artificial stability and servo-assistance for forced stability. My own view is that we must concentrate on introducing flight safety through improving the inherent aerodynamic qualities of the airplanes themselves. I recognize that it is a great temptation to go to artificial control and artificial stability. Certainly the developments in control theory and in electronic capabilities and in micro-circuitry lead in this direction, but I believe that we should resist the temptation.

The stall problem, for example, which has been discussed at some length -- we can certainly limit the elevator travel but that brings with it some disadvantages. If we combine that, however, with automatic slats, then we can have our high lift coefficients and we can still avoid the stall and we can be much less sensitive to center of gravity positions. My fear is that if we depend on the servo systems, we open up the possibility of multiple and sequential failures and, needless to say, we also complicate the airplane and increase its retail price.

In connection with the landing that Dave talked about, I would like to suggest that we need to improve the ground handling qualities. Certainly the tricycle gear was a first step in this direction, but anyone who has read the NTSB statistics is certainly aware that a large percentage of the accidents involve what is called ground loop and swerve. The interesting thing is that these airplanes are already on the ground. They are not impacting the ground. They are already there. I believe that the ground handling characteristics on a rollout particularly are going to become more important as we begin to tame the glide and the glide slope control problem.

In the following comments, I don't want to seem pessimistic about flight safety research or suggest that we reduce the R&D effort in this area. But I think that any designer is well aware of the fact that, no matter how much we improve the design and handling qualities of an airplane, the pilots and operators will frustrate these efforts very effectively and they will do it by using the safety features to extend the operating range of the aircraft. The Ercoupe is a good example. People began to treat it with less care than they should have because they knew it was not capable of stalling. The development of very high quality and sophisticated radio and communication equipment should have been a great inducement to safety. In actual fact, I think I am correct in saying that the weather-related accident rate has remained essentially the same, and the pilots have used the more sophisticated radios to fly into increasingly marginal conditions.

We need to consider some of the secondary consequences of the things we do in the guise of safety. For example, I would suggest at least a scenario without being sure that it is true at all, but certainly the tri-cycle gear made it possible for a number of people to learn to fly who could

never have learned to handle a tail dragger in a crosswind. This means that people with perhaps less good judgement that would have been weeded out before are now free to fly and exercise some poor judgement in a very critical situation where they are going to kill a lot of people. That leaves us with the crashworthiness that Frank Castellon talked about. He described the FAA program which is essentially sequential in operation and therefore probably the results won't be available for a number of years. The possibility of this occurred to me a couple of years ago and I began to see whether we could massage the NTSB statistics and see if we could get some hints from history at least and from the statistics as to how we could design aircraft for crashworthiness. I took as a measure the ratio of fatal accidents to total accidents for a series of given airplanes. Much of the data was taken from the ADIFZ study. Much of the additional data was obtained directly from the NTSB. It turns out that the ratio of fatal accidents to total accidents for about thirty-five airplanes varies from the worst to the best by a factor of about three to one. So we might expect to get some statistically valid results from that.

We would also be encouraged by the results of the new design Ag planes -- the modern design Ag planes -- following the Ag I which again is due to Fred Weick. The results of the new Ag planes have been very dramatic. Agricultural flying is basically a dangerous occupation. The accident rate itself remained essentially the same with the Pawnee, the AgI, the Snow, the Cessna Agwagon, and so on. The interesting thing is that the fatality rate was improved by a factor over the years of about three and a half to one. This was done by getting the hopper and the engine forward to soak up energy, strengthening the cockpit, providing good turnover structure, and cockpit dealthalization. What did I find when I looked at these statistics?

First of all, some of the conventional wisdom that we have all accepted in regard to aviation safety is literally not true. Some things are. For example, as you would expect, fast and complex aircraft have a higher fatality rate than the smaller and slower airplanes. However, there are two examples of misconceptions that I think are right important. One is that one particular airplane which has been widely heralded as being designed specifically for crashworthiness and has been held up as an example actually has a higher fatality rate than any of the others in its class. Another thing which I have been saying for years, that low wing airplanes generally have the potential for better crashworthiness, may not be true. I am not sure of the statistical validity of this, but high wings have a lower fatality rate (high wing airplanes in crashes) than low wing airplanes, and I am not quite sure why. Clearly this indicates that we need to do a great deal more in looking into the structure of aircraft and into the statistics to find out where we are really going rather than continuing on by what we have accepted as conventional wisdom.

Finally, I would like to applaud the FAA's crashworthiness program. It is certainly desirable. I suspect a lot of people here would believe it is long overdue. But I mentioned earlier that it is a sequential program and it is going to take years for the information to get into the general aviation aircraft. Furthermore, as I am sure you know, they are running into various procurement problems in getting pieces of the program out to the contractors. It seems to me that we need to look at something other than sequential

programs. We need to look at programs in parallel, but we need to look at some more imaginative programs and programs that take us somewhere down the line a little faster. For example, it seems reasonable to me that we know certain things about crashworthiness at least that would encourage us to go ahead with the development of crashworthiness prototypes much in the same way as DOT has gone ahead with its crashworthiness automobile program.

COLLINS: I would like to solicit answers from the audience to Bob Harper's first question. I can paraphrase it, I think. It was about the general aviation industry, how can you use the research results that have been achieved and referred to here today? And what sort of research would be helpful in this safety problem that we are not doing now and how could we do it? I would like to ask Bob, if here is the best possible flying qualities airplane from a safety point of view and over here is another airplane that you designed with your eyes closed absolutely knowing nothing, where in between these two is the typical airplane flying around today, the general aviation airplane?

HARPER: I learned to fly in 1944 in a Tandem Aeronca in State College, Pennsylvania. I thought that was the way all airplanes were. I graduated and went on and flew for many years. My son this summer took me for a ride in a tandem Aeronca of a more current version and made me fly it. He did take it up but then he let me fly it, and I just would not believe that I used to be able to fly something like that. It was no joke. It was a fun experience. I proceeded to take it apart and try to figure out what in the world was this machine, and I flew it for about an hour and a half. At the end of the hour and half, I had finally learned to fly it again and it was not all that bad. If the objective is to train people to close the loop on the controls, stay on top of the airplane, fly it every minute, I might draw it there. And that is worth thinking about because what is good for having me or you or somebody else use it in your business when you are not very current and when you are current, to cover the whole spectrum of your activities to efficiently get from hither to yon on a reasonable schedule might be entirely different in terms of the flying qualities that you might want to design into it, as compared to a training airplane where you are first training the guy to close the loop on the whole spectrum of airplanes that he might ultimately encounter in his career.

BERGEY: I don't believe in magic, that we are going to come up with schemes or designs that are going to change significantly the accident record. I truly believe that it is going to be evolutionary, and I believe that certainly the history of other technologies that have peaked and come down and changed will tend to bear that out. There is no question about it that it is discouraging to consider this aspect of it, that we are going to continue having fatal accidents with airplanes that have serious difficulties right now. But it is the sort of thing that we must deal with in all sorts of areas. We are dealing with the same thing in the energy crisis, as you well know, with automobiles that get 10 miles to the gallon and they are going to be with us for ten more years. In the sort of regulatory situation we have, I don't believe there is any other way of handling it but just let it run its course. I am afraid of prohibitions of any kind.



**QUESTION:** I wonder why we need to continue the grandfather clause. Once new improvements come along, old automobiles are put away. But old airplanes continue not only to be flown but continue to be manufactured. So why can't we put a time limit on a plane and ask the manufacturers to go back after a period of time and re-examine their plane in light of what we have learned in the meantime?

**ANSWER:** We certainly could. It is a matter of economics. I think we would have difficulty in getting any sort of legal justification in having the regulatory agency impose this on the flying public. If the flying public accepts the fact that safety is this important, then it can be done, but I am not optimistic about that happening. It might be worthwhile certainly to have a representative of one of the aircraft manufacturers speak on this point since they are the ones who would be most directly affected.

**COMMENT:** This is an interesting point, speaking now of survival. Why should there be this economic penalty which you just mentioned? If you take a look at two airplanes, say the Bonanza which was designed in the 40s, the Cessna 210 in the 60s. They sell for the same price, yet the 210 was recently certified, and the Bonanza was certified a couple of years ago. Why do they sell these aircraft for the same price if there is a certification penalty?

**ANSWER:** I am not quite sure how to answer that. The 210 probably did not cost a great deal more to certificate than the Bonanza. Furthermore, the cost of certification is a relatively modest cost over the entire life of an airplane, at least for an aircraft that is successful. The certification costs, in fact, are merely a down payment on the ability of the requirement to continue the development program. Certainly the Bonanza has had a great deal more invested in it over the years since 1946 than the original program. So I don't think the certification costs are truly significant in this area. But if you have obsolete airplanes already in the hands of people who have bought them in good faith, then you have an entirely different problem.

**QUESTION:** It is not so much requiring an airplane that is newly produced under an oldtime certificate to meet some of the requirements that have been introduced since the original certification process. We have to impose an economic penalty on the people who own previously produced units. One thing that strikes a particularly sensitive point with me is that airplanes that have been certified after a certain date are now required to have shoulder harnesses. It is only through the grace of the manufacturers that many of these airplanes now have these shoulder harnesses. Why shouldn't that be one of the things that is required of production aircraft?

ANSWER: I agree with you on that, and I think Frank Castellon could certainly speak to the difficulty of getting a change in the regulations through, even when it influences only those airplanes built after the new regulation goes in. With shoulder harnesses, strong seats, things of this sort I couldn't agree more. To change the entire aircraft, for example, for handling qualities and things of this sort, that is another ball game.

COMMENT: I would like to make one comment in connection with the point you brought up, Karl. You want to go back to as much inherent stability as possible. I guess I would have to agree with you that that is certainly a good thing to shoot for and, being in the business a long time, I feel that it is real important to try it that way. But to ignore the capabilities and the possibilities of using SAS we can't afford to do that any more. We have to recognize that, throughout the years, a lot of these things that I talked about have been known but really not applied in the detail that you need to get the overall response you are looking for. To me, that means that we really can't afford to pass up anything that could be used to improve the stall-spin record. Whether it is a very sophisticated SAS or just a simple stick shaker that motivates the pilot to do something about the approaching stall is a step in the right direction.

COMMENT: May I say something on the same point, Karl, of trying to get aerodynamic fixes for as many of the deficiencies as possible. We are coming to a greater and greater awareness of the influence of gust response of the airplane as we do this flying qualities work. Oftentimes the penalty of getting an aerodynamic solution to the problem is an excessive gust response which in turn leads to larger requirements on controllability, control power, and things like that. There is a definite trade here. There is a definite penalty for having excessive aerodynamic stability in an airplane. This should be factored into this use of automatics.

COMMENT: I wouldn't try to prioritize some of the solutions that I discussed this afternoon. We have to look at every possibility, and maybe I should have moved the artificial warning closer to the top and you would have been happy. If you did it correctly with the right margins and with the kind of thing that motivates the pilot to do something, because otherwise he is going to ignore it and in a stressful situation he can ignore it pretty easily, so you have to motivate him to do the correct thing. A stick shaker can do it if you make the amplitude large enough and increase the intensity as you get closer to the stall, then he wants to get out of that kind of situation. But you have to consider those aspects to make it successful.

COMMENT: I wonder if there is any pilot here who can say that he has never ignored or overridden a warning system before. A pilot who exercises poor judgement can override even the very best warning device

there is. I think every pilot here has done this, so that when we get to the essentials, I think many of us would be bound to agree with Mr. Bergey's proposals as the ideal.

COMMENT: I would like to ask a question of Mr. Castellon on the question of survivability. On your crash survivability R&D work that you are doing, has there been any consideration given to emulsified fuels or anything other than relocating tanks or recasing tanks for post-crash fire?

ANSWER: Yes, we have considered emulsified fuels. We are considering these fuels with relation to jets or jet type fuels which are not in the type of general aviation aircraft that we are talking about in the crashworthiness program. So I didn't speak about it here to this audience. We do have an emulsified fuel program. It is connected with transport aircraft. It is also being developed for helicopters. In the general aviation accident record, say the single and the twin engine airplanes, propeller-driven that we are talking about, something like 10 percent of the accidents result in fire. Although they do cause a great deal of fatalities, we try to aim our R&D dollar at the thing that will do the most good for the accident record.

COMMENT: On the business of the side force requirement, back in 1910, 1911, maybe even earlier than that, on very early bi-planes in particular without fuselages, with covering on them or anything like that so that resistance to side acceleration is probably pretty small. They have compensated for this by putting vertical panels in the inter-plane base between the wings. I imagine it was for that very reason that the airplane would tend to fly sideways without having any noticeable side acceleration. There was probably a recognition back even then that there was some good value, at least that they needed to fix it up. I have also heard that the B-49 tends to fly sideways that same way. I believe also that you can probably have too much in the way of this derivative CYBeta inasmuch as the bank angle required to develop a given sideslip gets to be too high. This is the one that, if you don't have the roll clearance or something like that, would allow you to drift off the runway. There probably is a need for a requirement. There is a maximum and a minimum. Seth might have a comment on what the numbers should be. The reason that there isn't a lot of evidence on this is that there haven't been very many variable side force airplanes around with which to investigate it and to try to determine max, min, and best.

ANDERSON: You are right. We really haven't done systematic research to look at this particular problem. Like everything, there is usually a tradeoff. I think the Breguet 941-STOL Aircraft, for example, has a pretty low side force characteristic. It is about one degree bank angle, offset five degrees of sideslip, and this turns out to be real good for that airplane because in a crosswind landing, you don't have to bank way over to keep your flight path straight. As a matter of fact, in some of the early flights on the Breguet 941, I remember that you had a pretty strong crosswind, 15 or 20 knots, and this thing approaches at 60 knots, so it was really

noticeable. But the pilot, in making the approach, hardly recognized there was a crosswind until they got on the ground and started to weather cock into the relative wind. To that kind of operation, this is an advantage. You have to consider all of the missions that are involved and narrow down to a particular thing for general aviation to help the pilot fly this flight path more precisely. All I can say is that there really hasn't been enough work done. Where you set the limits is going to determine how you are going to operate.

ELLIS: The comment on my apparent satisfaction with the situation for the landing approach, I don't maintain that we should be 100 percent satisfied with criteria, requirements, specs, or whatever, but in the work we have done, I have seen the fact that you can fly an airplane which has pretty poor characteristics on ILS approach, all kinds of wild motions and things like that which get deservedly downgraded. The criteria comes out that you can fly an approach with it. What I object to is trying to take that situation and extrapolate it to other flight conditions, especially if they might be more critical, and swashing around a plus or minus 10 feet on an ILS beam is not the same as doing the same sort of motion when you are trying to put the airplane on the ground.

MILLER: Mr. Ellis, how far have you or other people cranked in the average general aviation pilot in your test program and in what manner have you done it?

ELLIS: In the organized testing, we have done little due to limitations of time, money, design of experiment. We have had to resort to highly experienced trained evaluators, and the only way to link that to the average general aviation pilot is through the experience and knowledge of the particular evaluator. We don't normally ask him to take that frame of mind. We don't take off-the-street pilots normally, stick them in the airplane, and fly them. It takes too much flying time. Often you find in the business that you cannot draw really useful conclusions from simply how much the guy is flailing around in the cockpit. There is some judgement involved that can only come from an experience in evaluating. I might point out that the NASA Langley people in their use of airplanes like the instrumented 172, PA28, they are taking a different approach, in that they put an off-the-ramp general aviation pilot into the airplane, watch what he does, get some operating history, and try to pick out of the records and try to draw some conclusions from the results.

Just one specific example in our kind of work, you can set up a configuration. It is nearly impossible to hold anything but an average heading, you can struggle down an ILS with it. The trained evaluator will tell it as it is, that an airplane

should not be that way. You might take three or four general aviation pilots and three out of the four might struggle down an ILS and they will tell you they enjoyed it. That is the way airplanes are supposed to fly. With the limited amount of flight time we have, that is not the best way to get the answers.

COMMENT: I would like to direct a question to the panel in general with respect to FAA and/or NASA-funded projects. Are those agencies working on the possibilities of studying degradation in pilot proficiency with respect to the time spent in an atmosphere of noise that is common to the airplanes we now fly?

CASTELLON: We have done some with pilot-skill degradation. It has not been aimed at the degradation that may occur in a noisy cockpit. It has been aimed primarily at the degradation that occurs when a pilot perhaps does not practice certain maneuvers for a certain period of time or has been away from his initial flight training for several years and what has happened to the initial skills that he learned as a young pilot. We have published reports in this area, and it has been one of the bases used by the FAA recently to propose certain changes to the pilot requirements that are on the regulations right now concerning getting a pilot certificate. I don't know of anybody at FAA doing anything concerning noise.

**SESSION III - Regulatory Trends**

**Chairman, Archie Trammell  
Editor, Business and Commercial  
Aviation Magazine**

## Airworthiness Certification & Flight Safety Regulation

Dennis A. Tuck  
Flight Standards Service  
Federal Aviation Administration

The Flight Standards Service has the direct responsibility of insuring air safety. Of course, all of FAA plays an important role in supporting national security and achieving efficient air space utilization. Our doctrine, in dealing with airworthiness certification, is a systemworthiness concept. Particular attention and emphasis are given to the entire system in which the airman and his aircraft must operate. The system includes not only the airman and his aircraft, but airports, air navigation facilities, the air traffic system, the safety rules and operating procedures as well as the environmental factors, such as weather. In recent years, the appearance of public concern for noise and emissions has become additional important factors that must be dealt with in the systemworthiness concept. The introduction of the jumb jets into airline service with the wake turbulence effect they have on other aircraft, particularly the small general aviation aircraft, has caused reassessment of airspace utilization. The men of the FAA, therefore, must be disciplined in multi-dimensional areas so that this systemworthiness concept may be fulfilled. Trends in accident rates and causes along with airmen qualification and aircraft design induced problems are constantly being monitored and rules changed as service experience dictates or when determined to be in the public interest.

The stall/spin accident problem, small airplane crashworthiness, standardization of cockpit design, improvement of flight manuals are a few of the many aspects of safety that are of vital concern to the FAA.

We are aware of the need for interregional standardization of the application of the airworthiness rules so that one level of safety is maintained. We have published the Engineering Flight Test Handbook for Small Airplanes, and those handbooks for FAR 25 airplanes and FARs 27 and 29 helicopters will be published in the near future.

The FAA Flight Standards Service must weigh all information received from its own experience and research, experience and research of other nations and industries, and that of special interest groups to arrive at airworthiness and airman standards serving the public interest as a whole.

(The complete text is not available)

## Environmental Factors

E. W. Sellman  
Office of Environmental Quality  
Federal Aviation Administration

I'm going to discuss the status of U.S. noise and emission standards for business aircraft. Business aircraft are generally considered to be light weight types of aircraft, without regard to their type of power plant. For the purpose of establishing environmental standards, however, such classification is made.

In November 1969, the Federal Aviation Administration established FAR Part 36 to prescribe noise standards as a condition for aircraft certification and to limit the noise levels for subsonic transport category aircraft and subsonic turbojet powered aircraft regardless of category. Business jets certificated prior to the effective date of FAR 36 have noise levels near to, or in excess of, the limit specified. The introduction of turbofan engines has made it possible for new designs to be substantially quieter. This has led to a recent Notice of Proposed Rule Making which, if promulgated as a rule, will require that continued production of older designs be contingent upon their compliance with FAR 36.

With the exception of transport category, there are at present no U.S. propeller aircraft type certification requirements for noise. Countries that have adopted noise standards for general aviation propeller aircraft are Switzerland, West Germany, and Finland. Last March, a working group of the International Civil Aviation Organization (ICAO) adopted a recommendation which specifies measurement and correction procedures, as well as recommended noise limits for propeller aircraft under 12,500 pounds.

In the Federal Register of July 17, 1973, the Environmental Protection Agency issued aircraft emission standards for turbine and piston aircraft engines. On and after January 1, 1975, no fuel venting emissions shall be discharged into the atmosphere from any new or in-use general aviation gas turbine engine. Business jet engines and turboprops produced after January 1, 1979, have to meet rather difficult standards for carbon monoxide, hydrocarbons, oxides of nitrogen and smoke. Moreover, very stringent standards have been established for these types of engines certificated after January 1, 1981. Piston engines for general aviation aircraft produced after December 31, 1979, must comply with emission standards. Since the FAA is not convinced that the standards for piston engines can be safely met, a program has been proposed to develop and test methods of reducing emissions in order to meet EPA standards.

(The complete text is not available)



## Economics - General Aviation Cost Factors

Gene S. Mercer  
Chief, General Aviation/FAA Operations Branch  
Federal Aviation Administration

The broad classification of civil flying identified as general aviation contains many different use categories ranging from personal and business flying, involving transportation of personnel and cargo in corporate-owned aircraft, to special categories such as crop dusting, power and pipeline patrol, and aerial advertising. Aircraft types cover a wide spectrum, from single-engine piston aircraft to multi-engine jets. Since each use category has unique characteristics and requirements, future services and facilities must be tailored to meet those requirements.

The Federal Aviation Administration (FAA) has responsibility to develop, install, and operate the federal portion of a total and safe aviation system. Providing such a system requires orderly development in the use of navigable airspace, location of landing areas, federal airways, radar installations and all other aids and facilities for air navigation. That system should meet the needs of all users and beneficiaries and be commensurate with their abilities to finance it in such a manner as to promote continued orderly development and growth of aviation.

The modernization and expansion of the National Aviation System is being financed in part through the imposition of taxes on the System's users. Recently, the Department of Transportation (DOT) issued Part I of the Cost Allocation Study in which it was concluded that 30 percent of the cost of the National Aviation System could be attributed to general aviation. It was further concluded that the greater shortfall in taxes occurs in the general aviation sector since only about 20 percent of the costs assigned to general aviation are recovered through user taxes. If full cost recovery is to be achieved, substantial increases in general aviation user charges will be necessary. Industry spokesmen generally have taken the position that large increases in user taxes (or costs) will have an adverse impact on general aviation and will literally drive many aircraft from the sky.

Part II of the Cost Allocation Study to be completed by the DOT, will address needed changes in tax structure that can be made without compromising or overriding the primary objective of adequate air safety. The Department's analysts will specifically address proposed changes in methods of cost recovery and will include recommendations and proposals for legislative action. They have stated that in preparing recommendations to Congress, they will adhere to the principle of reasonableness and gradualism in the generation of any new user taxes.

The FAA's Ten Year Plan for Development of the National Aviation System will also affect general aviation costs in two major ways; by increasing airborne equipment requirements and by additional regulatory action. It may be that further operational or regulatory constraints will be required to assure the safe and efficient operation of the system.

Shown on Chart No. 1 are projections of instrument operations at airports with FAA traffic control service. In 1969, the first Terminal Control Area (TCA) was established. Today, there are ten airports with high levels of air carrier activity at which all aircraft within the TCA, whether flying under instrument rules or visual flight rules, are provided separation service. Similar air traffic rules and procedures are planned at 23 airports by 1975. Additionally, expanded area radar service at all FAA radar locations will involve radar control of most operations within a 25-mile radius of the primary airport. These new rules and regulations account for much of the spurt in general aviation instrument flying and anticipated future growth.

Current aviation forecasts to the mid-1980's indicate that general aviation flying will be responsible for about 90 percent of the growth in total aircraft operations and account for over 80 percent of total operations at FAA air traffic control towers by 1985. Chart No. 2 reflects the growth of aircraft operations at airports with FAA traffic control service. The chart dramatically highlights the historical and projected growth of general aviation activity. Based on these forecasts of growth, the FAA plans expansion of facilities to meet the indicated future demand. In 1968, there were 226 control towers, 362 in 1973, and 476 planned for 1985. Should the forecasts prove too high, the demand for FAA services will be less than anticipated.

Also, note that in absolute terms, a decline in operations occurred. General aviation activity in Florida declined significantly. California also reported declines, but showed signs of recovery much sooner than Florida. Initially this decline was attributed to the economic slowdown. However, when activity continued to be weak despite improvement in the economy, other factors were examined. One was the premise that TCA's might depress general aviation flying. However, airports with TCA regulations in effect reflected no significant difference in activity from the balance of the system.

Historically, general aviation forecasts have not taken into account, on a systematic basis, the effect of increases in operating and investment costs resulting from changes in federal regulations or user taxes. Excluding costs from the demand equations tend to produce long-run positive biases in the forecast.

Because of recent increases in the costs of owning and operating general aviation aircraft and the concurrent slowdown in general aviation growth, the FAA decided to employ Battelle Memorial Institute to conduct a General Aviation Cost Impact Study. The purpose of the study was to determine the effect of changes in ownership (fixed) and operating (variable) costs on general aviation activity. Particular emphasis was placed on those costs stemming from changes in the federal regulatory environment and higher federal aviation user charges.

The study first developed a data base of ownership and operating costs in each segment of general aviation, i.e., personal, business, instruction, etc., by various aircraft types. Then regression equations were developed which related the demand for aircraft and flight hours to the appropriate cost categories.

The study result indicates that the demand generated for general aviation activity is significantly affected by changes in either ownership or operating costs. Further, there are significant differences in the impact of cost changes on activity levels among the different segments of general aviation. Personal flying and air taxi operations were found to be the most sensitive

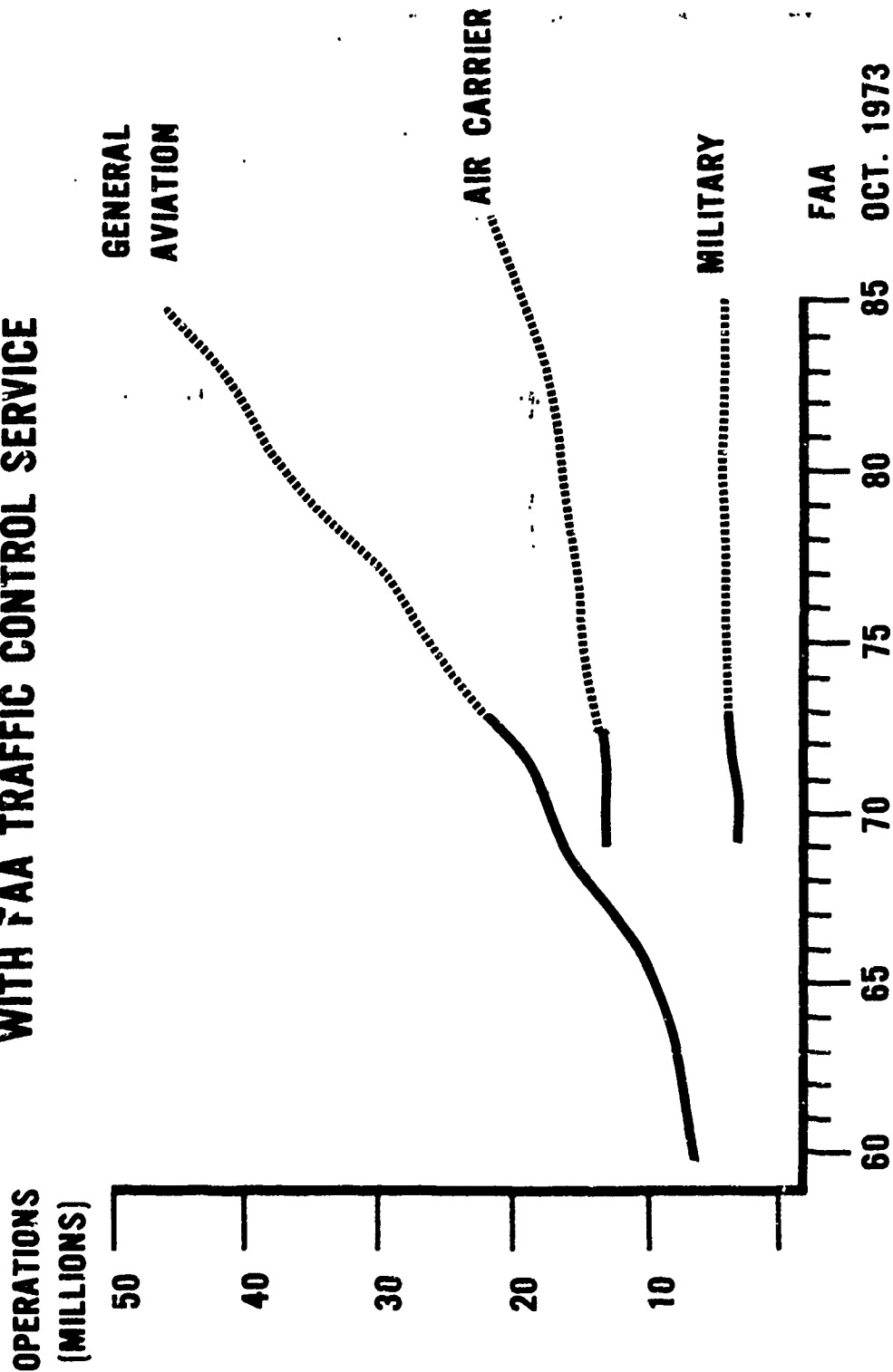
to changes in fixed costs (ownership or investment type costs), while instructional and industrial/special were found to be the least sensitive to changes in costs that do not vary by the volume of use. The categories most sensitive to changes in variable costs (cost related to hours flown) were instruction and aerial application, while the least sensitive to changes in direct operating or out-of-pocket costs were air taxi and business and executive use categories. It is significant to note that the personal category which accounts for about 55 percent of the general aviation fleet and about 25 percent of total hours flown, showed relatively high sensitivity to changes in both types of costs.

Chart No. 3 summarizes impacts of percent changes in activity (elasticities) for each 1 percent change in cost. For example, a 10.0 percent increase in fixed cost would result in a 12.03 percent decrease in the number of aircraft in the business and executive fleet. Likewise, a 10.0 percent increase in variable cost would result in 6.59 percent decrease in the hours flown by the business and executive fleet.

If applied uniformly to all segments, a specific cost change would result in significantly different impact on each segment of aviation. Therefore, it is important to consider these different impacts, since a cost change might have only a nominal impact on activity in one segment, but could have a severe impact on another. If user taxes were imposed on the general aviation community to effect full-cost recovery, there would be a reduction in the demand for flying as well as in the tax base from which these costs could be recovered. However, with less demand, there should also be some offsetting reduction in the cost of operating the National Aviation System.

Using the methods developed by the Battelle study, it is now possible to measure the impact of proposed regulatory or operational changes affecting costs on the level of general aviation activity. Consideration of such a cost impact will enhance the quality of decision-making within the Federal Government and should provide improved general aviation forecasts. The four volumes of the Battelle study are now available from the FAA. Volume I contains an executive summary of the study and a discussion of conclusions. Volume II details the methodology used in developing the data. Volume III contains instructions for use of the study, and Volume IV comprises the data base.

# INSTRUMENT OPERATIONS AT AIRPORTS WITH FAA TRAFFIC CONTROL SERVICE



FAA OCT. 1973

Chart No. 1

# TOTAL AIRCRAFT OPERATIONS AT AIRPORTS WITH FAA TRAFFIC CONTROL SERVICE

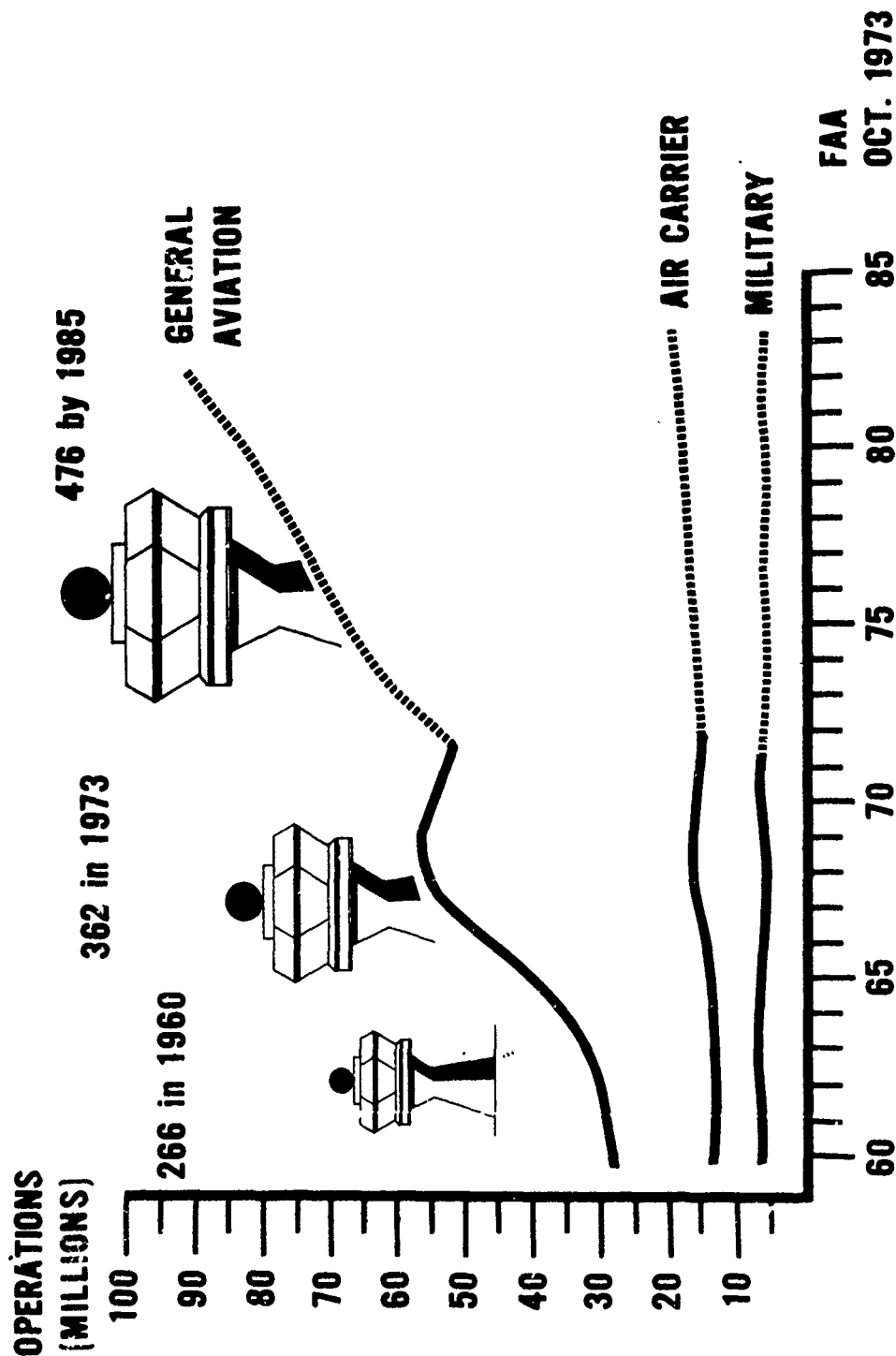


Chart No. 2

# GENERAL AVIATION COST IMPACT STUDY

## COMPARISONS OF ELASTICITY

| USER CATEGORY             | FIXED COST<br>ELASTICITY | VARIABLE COST<br>ELASTICITY |
|---------------------------|--------------------------|-----------------------------|
| BUSINESS AND<br>EXECUTIVE | 1.203                    | 0.659                       |
| PERSONAL                  | 3.578                    | 1.350                       |
| AIR TAXI                  | 4.516                    | 0.304                       |
| INSTRUCTIONAL             | 0.478                    | 2.237                       |
| AERIAL<br>APPLICATION     | 2.277                    | 1.695                       |
| INDUSTRIAL<br>SPECIAL     | 0.852                    | 0.772                       |

Chart No. 3

DISCUSSION - SESSION III

REGULATORY TRENDS

George D. Kittredge, Sr.  
Senior Technical Advisor  
Environmental Protection Agency

My comments will supplement the remarks by the other speakers and give you, hopefully, a little additional background on the Environmental Protection Agency's activities with respect to engines powering general aviation type aircraft. In putting together my notes independently of the other speakers, I chose to emphasize most heavily the portion of our activities that relates to piston engines. However, in the latter discussion period, certainly we can talk about the turbine components of the general aviation field as well.

In 1969, we found that there were no available pollutant emissions measurements which apply to engines of the opposed piston type other than Volkswagens. So we initiated a contract study with Scott Research Laboratory to measure the carbon monoxide, hydrocarbons and nitrogen oxides during actual flight conditions using a series of instrumented light aircraft. A total of nine of these was tested. From this, we developed a working knowledge of the pollutant emissions characteristics that seem to accompany landing and takeoff operations by aircraft. It turned out that, as a result of the essentially rich mixture operating characteristics of these engines during low altitude flight and ground operations, the carbon monoxide emissions were quite high, the hydrocarbon emissions in terms of pounds per pound of fuel burned were about the same as pre-1968, or in other words pre-emission controlled passenger cars, while nitrogen oxide emissions were very low. Therefore, this served to show that when emissions from aircraft of this type needed to be controlled, emphasis should be placed first on carbon monoxide and, secondly, on hydrocarbon reductions. Following the signing into law of the Clean Air Act of 1970 described by Mr. Sellman and the responsibilities which this gave to EPA with respect to emissions standards for aircraft, we carried out additional tests through two different contracts to expand our inventory of information on the emissions characteristics of opposed piston light aircraft engines.

One of these was carried out using leased aircraft, but this time with the emissions measured while the aircraft were fixed in place on the ground and the engines operating through simulated landing, takeoff cycles.

The second of the contracts was with Teledyne Continental. It consisted of dynamometer tests of engines of their manufacture at their laboratories at Muskegon, Michigan. A total of 70 engines was tested during both of these two contracts, and the results essentially showed us that the earlier flight tests were about correct; that is, the carbon monoxide and hydrocarbon emissions were quite high relative to controlled automobile engines, while nitrogen oxide emissions were so low as to indicate that only minimal emphasis needed to be placed on reduction. This work also gave us the basis for a workable testing procedure which was potentially useful for laboratory testing of engines in certification programs.



Concurrently with the engine testing programs, an analysis was being made by our North Carolina Research Center looking into the impact of all forms of aircraft operations on air quality. With respect to general aviation, attention was given to airports in which light aircraft operations played a dominating role to try to identify their independent effects on air quality in the immediate surrounding of such airports. While it is true that on a nationwide basis, as mentioned by Mr. Sellman (or actually even on a regional basis) current emissions from light aircraft operations are very small, well below one percent, it does nevertheless appear that in the immediate vicinities of the airports themselves, future contributions (future meaning post-1980) will by no means be insignificant. Using the Van Nuys airport as an example, it was shown that carbon monoxide emissions projected through 1980 could amount to roughly 4,000 tons per year which can be compared with Washington National Airport, as an air carrier dominant airport, which by that time will show about 3,000 tons per year attributable to aircraft operations, in other words, about the same. Thus, the carbon monoxide emissions from aircraft operations could be expected to have a meaningful influence on the carbon monoxide levels in the ambient air in and around the airport property to which workers and travelers in the airport vicinity would be exposed.

The justification for control of CO and to a lesser extent hydrocarbons from aircraft, therefore, seems to be about as strong as that applying to commercial aircraft in larger metropolitan terminals. Because of this, when the federal emissions standards applicable to aircraft were released in July of this year, they contained requirements applicable to engines in this category which must be met by December 1979.

To develop the basic information that we needed to predict the approaches to control of emissions from these engines and their costs and effectiveness, a contract project was conducted with Bendix Laboratories in Southfield, Michigan. Bendix investigators looked at the kinds of approaches being used in automobile engines and attempted to pick out from this background those techniques that offered reasonable prospects for application to light aircraft operations, considering both safety and operating costs. The kinds of approaches which they examined included catalytic exhaust system reactors, thermal exhaust system reactors, spark advance retarded from the normal setting, air injection into the exhaust manifold, and finally carburetor air-fuel mixture settings adjusted to achieve mixtures leaner than those presently utilized, particularly under ground operating conditions. Of these, it was concluded that further development of emissions control from aircraft piston engines emphasizing carbon monoxide and hydrocarbons should initially look into field and air management as opposed to exhaust gas treatment as the potentially most promising paths to take.

Accordingly, we have, as Ed mentioned, based on our standards on this form of technology, assuming that they will probably be met by the manufacturers by techniques based on improvements to carburetion, improved intake manifold design, possibly greater use of fuel injection, and other approaches to maximizing engine operation at lean best-power, air-fuel ratios, during engine operating modes exclusive of takeoff. We realize that this will involve some engine design tradeoffs and possibly added costs. In the environmental area, very little advancement seems to come at no cost. As a byproduct

however, it should offer very significant savings in fuel consumption. With the present widely publicized concern over energy depletion and greater emphasis on maximization of fuel economy in all internal combustion engine applications, the latter may turn out to be as strong as the emissions arguments for such lean mixture designs.

With the uncertainty that is inherent in basing regulations which become applicable only six years from now and are hence based on undeveloped technology, we have provided provisions for re-analysis of these regulations on a continuing basis up to that time, and this could, of course, result in some readjustment of the standards, either up or down, prior to December 1979, effective date. However, the requirements represented by these regulations are quite modest compared to the passenger car standards and, in fact, were met by ten out of the seventy engines which were tested by our contractors in 1971. We do not dispute Ed's estimate that on the average a 50 percent reduction will be required, but we wish to point out that if you look at individual power plants as typifying what might be accomplished, some were achieving these standards two years ago.

We are confident that the industry represented here will respond to this challenge and achieve cleaner burning, more efficient engines to power general aviation aircraft for the post-1979 era.

QUESTION: Would a 10 percent reduction in general aviation use result in a 10 percent reduction in Government cost? Are we in a situation where there may be a reduction in revenue without a corresponding reduction in costs and thus the cost per flight will have to increase in order to have income to meet outgo?

ANSWER: That is why the department has specified that they will have reasonableness and gradualness in imposing this.

QUESTION: Is there general agreement with the data base which led to the 20 percent - 30 percent allocation?

ANSWER: This is one of the main parts of the DOT cost allocation study. Fifty percent attributed to air carrier, 30 percent to general aviation and 20 percent to military. There is a disagreement because general aviation does maintain that perhaps they are being forced to use this part of the system that they really don't need to use, and at what level should they be charged. Nobody was happy with the cost allocation study result.

COMMENT: In answer to your question there is a great deal of dispute over the 20-30-50 split. In fact, there is still quite a bit of confusion. Some people believe that 20 percent assigned to general aviation was a public benefit allowance, but as I understand it, it was not. It was an allowance to cover the cost of military and Government flying. The report does not make allowance for any public benefit.

QUESTION: Isn't there another more deeply based problem in that the recovery of the costs for the air carrier is simply passed on?

ANSWER: Yes, this Part I of the report addresses itself to that problem and suggests that there should be a change so that the air carriers pay more directly.

QUESTION: My question has to do with the research and development in connection with updating criteria for certification.

Over the years, our experience has been that when you look at some of the criteria, it appears that the application of today's criteria to airplane design appears to be more of an art than a science. Even today, there seem to be so many subtleties that I wonder if the FAA has ever considered some kind of review and updating program to see just how these criteria are applied, particularly with respect to high performance airplanes.

TUCK: I am not personally a flutter expert, so I can't get too deep in the subject but I do know that our engineering people are working on the flutter problem and have an active interest in covering the aircraft adequately with the increased speed ranges. They

are coming up with new techniques and new ways of handling the problem. There are a couple of instances where he had flutter problems in service that pointed to a need for improvement in the methods that we use to handle it.

COMMENT: Since this subject did come up yesterday, it is one that perhaps we should zero in on and see what kind of input we can get. When Dennis mentioned it this morning, I happened to recall one airplane which was certified in 1937, and stayed in production into 1969. It was changed considerably in that 32 years by STC's. How big a problem is that, and what should we do to correct it?

ANSWER: We could set categories of change. We talked yesterday about airframe changes with handling qualities, and so on. But it does seem to me strange that some airplanes, for example aren't required to have rotating beacons, because of their early certification. So when it comes to protective devices and things of this sort, it seems to me the grandfather clauses should be abrogated.

COMMENT: I believe there is a precedent about to be set on the grandfather clause in the case of noise. The aircraft that do not meet the proposed noise standards will have to be fixed in December 1974. Should we be reviewing the certification of these airplanes that stay in production every five years, every ten years?

COMMENT: I am not in the business of building airplanes, and I am frankly surprised and I didn't even know that people could continue to build general aviation airplanes with a certificate that is that old. Can you change the fuselage, the wings the landing gear on an airplane and not get a new certificate? What do you have to do to show the FAA that those changes that you have made as the manufacturer are safe?

TUCK: Actually the changes don't come all at once. They come gradually year by year and model by model. By and large, most of the changes from one model year to the next are fairly minor, perhaps 200 pound gross weight increase, a 1/4 inch c.g. next year. They may come out with an improved engine, up the horsepower a little bit. But over the years, these changes can amount to something significant. The regulations as they are now written and have been for many years allow minor changes to aircraft from year to year. We have something of a bigger problem in general aviation because we don't have a turnover. We have a turnover in air carrier type aircraft. We have a new generation about every fifteen or twenty years where we start from scratch. This problem doesn't exist to that degree anywhere else except with general aviation. I would hope that we will be able to do something about it before too long. We are working on the problem, and we recognize it as a problem, especially in general aviation airplanes.

QUESTION: I always thought the grandfather clauses meant that somebody couldn't come along and make you put a whole lot of money into it or throw it away or something like that. Or if you are already a test pilot with regard to the military and they change the regulations so that you can't possibly meet the new regulations that you establish yourself as being okay. But I am really surprised to hear people talk about grandfather clauses with regard to new production. I think I agree with Dennis that it seems to me we ought to reconsider what are minor changes, because minor changes can integrate into a major change over a period of time. Regulations should in some way address that possibility since it does exist.

COMMENT: I think we may be getting off the track a bit with regard to regulations. We immediately assume that if an airplane was certified in 1937, it is a dangerous airplane now. But let's go back and take a look at the Cubs. They started with a 40 h.p., up until now it is the Supercub. You could say it is certified under the regulation, but in reality, the AN4 bolt that it uses now is the same identical size as what they used in 1937, but it is stronger now and it is much better. The wheels and brakes are better now. They hydraulic lines are better now. The airplane isn't dangerous and bad just because it was designed and certified some time ago. That doesn't mean that there haven't been some regulations that have come along in certification that the never certified airplane is not definitely improved by. But the changes that come along, the twin Beech is 450 h.p. It has been that for 30 years or so. So we can't automatically assume that because the certification was done sometime ago that now it becomes an unsafe airplane. It could be just the opposite.

COMMENT: But if you do change it over the years, if you make alterations beyond what it was originally certified to be, then I submit to the audience that you should at least consider this so-called new airplane in the light of the old regulations.

MILLER: Just to set the record straight -- and I don't mean to argue with Mr. Tuck too much -- not too long ago, the Board had occasion to make a recommendation regarding the F27 and F227. People are still being killed in those aircraft because there aren't shoulder harnesses for the flight crews. This airplane was originally certified something like 15 years ago. Apropos of the whole discussion here, I submit it may be somewhat academic for the FAA and the manufacturers to argue to this point. I am referring now to the trend in the courts. If there is one thing the courts have decided relative to airplane litigation in the past decade, it is that they don't give a damn what

the regulation says. The public -- and I am referring to the relatives of people who might be killed in these airplanes -- you are not going to defend against this in the courtroom today by saying, "This plane was certified under this situation and that's it." This is what the manufacturers are up against whether they want to admit it or not. If there is a state of the art change that will increase safety and it is relatively minor, something other than putting an extra engine on or something like that, the public is demanding that these changes be put in or the manufacturers and/or the FAA is going to pay through the nose.

**TUCK:** What you say is absolutely true and the manufacturers are aware of it. The other thing though I don't think the situation is near as grim as it sounds, and if you don't believe that just try to get an STC. These things are considered. If you make a change to an airplane, whether you are a manufacturer or an individual or someone else, you do have to consider later reservations on a matter of policy, so I don't think they are completely ignored at all.

**COMMENT:** In view of what we have heard here in the last two days, I wonder if it isn't time for the researchers, the FAA, and the manufacturers to get together in considering the complete white paper change to Part 23 such as was done in '61 and it is in the works with 141 now.

**TUCK:** I don't think it is being actively worked on as a complete rewrite. We have some specific problem areas that we would like to see some changes take place. One of them is my own area, the flight area. We are due some major changes in the flight requirements in Part 23 especially.

**COMMENT:** In deference to many of my abler colleagues here, for years I have been doing the popular end of this legal thing. Chuck is completely right and has been for almost the word go. The lawyers aren't going to wait and succeed against manufacturers, for example. But curiously, the case law refuses to stomach the further proposition, and while you can stick the Government for many, many things, as yet the majority of the cases do not find the Government role in this thing as one which is remediable by paying damages.

Back on Mr. Mercer's topic, just so that it is known to everyone here, the other team has not been idle and there is available for you to obtain a review of cost allocation status and its effects on general aviation which officially was published on March 23 of this year. You get it from the AOPA and GAMA. "Review of Cost Allocation Status and its Effects on General Aviation," Genovac, Battelle.

COMMENT: The certification question regarding the Government is still accurate. It is considered a discretionary function. We can't be sued for that kind of activity. It is in the best interests of all of you if that continues to be the case, because while in short term spreading the burden on the Federal Government might help, in the long term certification requirements would become so stringent that the cost of machines would go clear out of sight.

TUCK: Comments that were made earlier about our regulations, about regulating aviation and in many cases bad regulations, etc. To put out an NPRN on new 61, there were 750,000 pilots who received 1600 comments, and a lot of those comments said, it is no good. I have some expert people in my branch that are involved in writing these regulations, but they are just individuals. Any of the regulations, NPRN's that we put out, we need the expertise in the industry to give us comments. GAMA gave us some good comments on 141 and told us why what we were proposing was not good and what should be proposed. I don't expect an answer from the group. It is something you should consider. How many of you answered to the NPRN on 61?

QUESTION: Are you publicizing the NPRN's in anything but the Federal Register?

TUCK: We don't have the facilities to publicize them other than the Federal Register, and the extra copies that are made and sent out to the subscribers to the parts. Your periodicals do discuss it, but too often they don't go out and ask for comments from the public that reads them. Piper has a very good article in one of the magazines telling about the procedures, and if we had more of your help, then we don't think we would be charged with bad regulations.

COMMENT: This goes back to what a man said very badly at the beginning of this. If we have bad regulations, it is really our fault for not getting together and offering something better or at least commenting on a thing with some intelligence or trying to get together and decide among ourselves what we want in lieu of what we get.

PAUL SAUNDERS, CANADA: I have been listening with great interest the past day and a half to many voices. I concur that we have a problem that is mutual in Canada and the U.S. In this last discussion one thing that came to mind, many of the aircraft flying today, if taken as they are operated, wouldn't meet with some aspects of this certification problem. For example, en route climb requirements, single engine. During certification of this aircraft performed by professionals who knew the aircraft intimately, he knew for example when he was going to have power reduction to

do a single engine Vmc. What about considering the requirements of the certification that could be met by the average pilot who is going to operate the aircraft. What happens to the stability of the aircraft when it suddenly loses power during maximum power on the other engine, when you develop a divergent stall with a slip angle helping an increased angle of attack on the tail? There are a lot of things in certification that demonstrate the aircraft meet all these requirements, but it is done with people knowing the aircraft intimately, knowing what is going to happen next. When some poor guy who is not too adequately trained to start with gets in the aircraft and meets this condition, we have an accident.

TUCK: I think that is an age-old problem, and it is between the exercise of good judgement in evaluating airplane handling qualities on the part of the people doing the tests and a balance between training the pilots who are going to fly them. We will have it with us to some degree forever, but it is something we should be concerned about and be trying to provide in our certification procedures, providing a safe airplane that the general aviation pilot with his experience level can be expected to handle.

QUESTION: Is the technology such that we could understand the pilot well enough to build an airplane for certain kinds of pilots and exclude other kinds from flying that aircraft?

TUCK: That would be pretty difficult. In general aviation, we probably have the broadest possible band of experience in training levels anywhere in the aviation industry. We are trying with one set of rules applying to airplanes of nine passengers or less to cover all these types of aircraft.

QUESTION: Is that wise?

TUCK: I don't know. I have given some thought to this as a possible problem area. This is my own personal opinion. It is a problem that is growing much more so than it was 20 years ago. It may be something that needs further consideration. The different categories of aircraft in general aviation from the complex twin turbo prop that is operated by professionals and the single engine Comanche or Cherokee, say, that is operated by an inexperienced pilot for pleasure or his own personal business applications. There is a big difference between both the aircraft, the usage of the aircraft, and the experience levels of the pilots involved.

QUESTION: The recommendation has been made to the FAA from several sources in the last couple years on the possibility of having a single



source policy office. Certainly the flight test branch would be called on to make a policy input as much as any other branch of the FAA and possibly more, especially as we are talking about regulatory changes. My question is has there been any planning or discussion of a situation like this, of establishing an FAA office that was single and central, to deal with policy matters to eliminate the inconsistencies that invariably occur in the nine regions?

**SLAUGHTER:** This matter has been discussed within the FAA. No decisions have been made to change or reorganize other than maintain the nine-region concept. There are problems with regard to consistency between regions and establishing policy and we have been trying to take care of this through our in-house programs, like Mr. Tuck has established in flight test and putting out flight test guides to provide a document which will prescribe the policy.

I would like to go on and speak about two or three other things that have come to the floor as a question. One was the flutter situation. We have recognized that the flutter criteria for very light airplanes were simplified many years ago to allow a simplified assessment of the flutter characteristics of the aircraft. This criteria was not envisaged for the high performance light airplanes, and our recent policy to give field people tools to deal with the high performance aircraft does not allow this simplified flutter criteria to be used.

With regard to the remark about high performance aircraft, I assume that he was speaking with regard to the high performance small aircraft and not the large jet aircraft. We are all aware that those aircraft need very stringent assessment criteria for flutter substantiation.

I am given the impression here today that when we vicariously refer to the grandfather clause that no assessment at all is made with regard to aircraft that get changes. We do assess changes to aircraft on the same stringent assessment basis as we do the original certification of the aircraft. Where there are significant changes to an airplane or new or novel design features where safety could be vitally involved, the FAA sets forth a series of what we call special conditions (it is ad hoc rule-making in effect) to assess and upgrade the standards which would be applied to this new modification to the aircraft. We all should recognize that we do this sometimes to the critical assessment by the manufacturers.

One other thing with regard to interface with the public, with the manufacturers, and with those that are interested in upgrading the role, the FAA now has in-house under active

consideration a proposal to conduct a periodic airworthiness review. We did this some ten years ago. It was very effective at that time. We are going to attempt next year to resurrect this, and we hope that we will get the participation of those that are vitally interested in making proposals to upgrade the safety standards.

**COMMENT:** Is it true, or is it not true, that we have aircraft in production today that, if the manufacturer came to you today and asked for a certificate, he could not get it?

**COMMENT:** Suppose he does not have a type certificate on the aircraft. Suppose you wiped out all the type certificates tomorrow, would all aircraft in production today meet today's rules for certification?

**ANSWER:** If we wiped out the type certificates, for a manufacturer to continue in production he would have to apply for a new type certificate. That is correct.

**QUESTION:** Would all airplanes in production today qualify in that case?

**ANSWER:** Some airplanes in production could not meet today's criteria if you applied for a production certificate today.

**WOLFE:** Earlier the question was asked how to prevent over-regulation. Some of the older people here can resort to history. It almost seems, if you go through each decade of the history of aviation, nothing is new. In 1938 or '39, we had gotten into three or four telephone book volumes of civil air regulations, and I made the mistake of getting my neck out and mentioning this to Dr. Ed Warner. I said one thing we might do is to take the regulations that we had in 1929 under the Air Commerce Department and enforce them and see where we get. The next day I was made an examiner! With the impact of that, Ed Warner was able, during his term as head of the CAA, to take those three or four telephone books and get them down to our present set of regulations in the area of flying, for example. As you read the reports coming up today, enforcement is doing better than it has been doing. I know I will be one of the most unpopular people with many people whose love I crave, but even a strict enforcement right through the book would help in that area, and that is one small answer to that question of the over-multiplication or regulations.

Just to be quite specific, for example, the carriage of the fire extinguisher thing, when they started to look at our fire extinguishers and penalized us for it, they found out it was just ridiculous, and today we don't have it which was always empty anyhow. The next one that I think of is the way you were

to taxi. You were to taxi by moving your nose from side to side, and it got ridiculous because we all had different kinds of airplanes. We had different ways of handling our taxiing, and they agreed to cut that out and get back to reckless, careless flying. These are some of the areas where you can reduce regulation and where enforcement, even in Mr. Tuck's area, would keep the danger of over-regulation out.

**COMMENT:** I believe there is a project behind the scenes at FAA, and has been given a year or so, at least to simplify the language in the regulations.

**BRITISH CIVIL AVIATION AUTHORITY:** It may interest you to know that 67 percent at my last count of general aviation aircraft in Britain were made in America. Of this 67 percent, something like 80 or 90 percent were made under the DQA system. In other words, without specific over the-shoulder control by FAA, but overall policing and nurse-maiding the situation. What worries me about the discussion this morning, there seems to be an acceptance that the FAR's -- the irreducible minimum below which no one should go, and I would like to think that is what they are. I would like to think that no aircraft designer or constructor is looking down on the FAR's. If he did so, I think you would have far worse aircraft in service than you, in fact, have.

Your record doesn't say that you produce bad errors, and I would like you to bear in mind to carry this thing with you, that the responsibility for our safety record in general aviation rests very much with your constructors. Your constructors carry responsibility throughout the world. If they did work entirely on precise and strict confinement to regulations, both American business and the American image would suffer in the general aviation field. So don't let us assume that it is the FAA that defines the standard of American aircraft. They define the standard below which they should not go.

**SESSION IV**

**Prospects for an Improved Safety Record**

**Chairman, John L. Baker  
Assistant Administrator for  
General Aviation, FAA**

John L. Baker  
Assistant Administrator for General Aviation  
Federal Aviation Administration

The topic of this panel is where do we go from here. In theory, at least, it should represent the culmination of the activities that have preceded it. My approach to what has happened is relatively pragmatic. I would hope that each of us when we leave here doesn't pat himself on the back and say that we have done our bit for safety and not worry about it for another year. The ultimate question is, is this going to accomplish something? Have we accomplished something? Have we at least planted the seeds to accomplish something? My measurement of whether we have or not is whether or not the user gets something from this in the near future, because if, in fact, we are an artistic success and nothing gets out into the field, we have wasted our time and your time and the university's facilities.

I have an observation about aviation and general aviation in particular. We oftentimes seem to adopt the posture here that after we have self-emulation and we have solved our problem, then it is somebody else's problem tomorrow. I think we are increasingly aware that our problems are system problems and they run across the entire aviation community from the governmental side through to the most elemental pilot who is just starting in the system.

To some extent, I am dismayed that I do not see the policy-makers from the major general aviation companies here. I do not mean to demean the people who are here. I think that we need the engineering competence dramatically in general aviation, but I also think that if we are going to have impact on the hardware that flows out to the user, we have to influence the policy-makers as well as the technical people.

The second observation I would make is that many of the things I heard here are not hardware problems. They are education problems. I think that each of you holds to the belief that the machines we have are the best in the world and I believe that. Personally, I have been flying them 30 years, give or take. Obviously each of us would like something different tailored to our particular likes and dislikes or unique skills. However, someone mentioned yesterday and I think it is true, that the ingenious nature of our constituency is such that if you build an airplane to a particular standard, there are people who can find ways to push it beyond that. It would seem to me that all of us have a responsibility to insure that the pilot and community recognize that the handbook is the way to operate the machine. It is incumbent on all of us to insure that the handbook does tell him how to safely operate the machine and to impress upon him that to go beyond those parameters is to risk bodily injury to say the least, because you can count on being the first guy at the scene of the accident if you ignore some of the things that are spelled out there.

Yesterday afternoon, I heard very little that sounded as though there were simple solutions that would give us relatively immediate return. That is what I am concerned with. I would like to see something happen tomorrow.

I have been around thirty years and have not seen much happen in terms of making the machines better handling. I recognize that there is a dilemma of tremendous dimensions when we decide how we are going to design airplanes or how our rules are going to be written in terms of certification. Do we certificate an airplane to the minimum pilot skill in which case we are making the pocketbook determine who is qualified and who is not? If you have the money, you can kill yourself in an expensive airplane rather than a cheap one. That philosophy offends me somewhat. Do we build it to the average pilot's skill? Do we tailor the airplane to the mission and then have various classifications on pilots to exclude those people who simply are not qualified for flying airplanes because they can pay for them? I did not hear that discussed. I think it is a relevant consideration. I know that we have gone through the exercise -- in fact, Dave Thomas at one time looked at this very hard. Unhappily, it was titled with the euphemism "Junior Birdman," "Semi-junior Birdman," which killed it in short order, as you can imagine, because nobody with the dare and do of all us pilots wants to be called a junior birdman with the skill that we all obviously have.

The other concern I have is, are we coming up with the solution to real problems that are going to have an immediate payoff or are we coming up with solutions that represent inquiry into interesting problems which I assume the good engineer is really looking at. If we are looking at interesting problems and concerned with being artistic successes, I think we are wasting our time, and we are wasting your time and capabilities. I have the feeling that the insurance carrier probably have the solutions to many of our problems, because they approach the problem of accidents very systematically. The FAA, so far as I know at least, get very little input. I would assume that the rest of you in the aviation community get very little from them either and we have had very little input from them here. The user groups have been more than a little quiet here also, and I would think that they have vested interest to insure that the demand goes out to the people that are certificating airplanes, designing airplanes and selling airplanes that they get products that are usable and safe and that meet the specific requirements that they have for the machine. I hear very little of that. I usually hear that we are going to solve all the problems in aviation if we eliminate the FAA. While that may be a giant first step, that is not in fact going to solve your problems because ultimately it is you and the airplane that are going to work out the compromise, and gravity and hard surfaces I guess make the equation.

The other area we are soliciting your comments for is across the government. Are we, in fact, allocating our resources properly? Is there too much emphasis on an artistic air traffic system and too little emphasis on R and D research, inspectors in the field, surveillance of flight schools, surveillance of manufacturers -- these kinds of things? Do we spend too much money on the exotic and too little on the practical? Do we seek your counsel too seldom and tell you too often what your opinion is? Those are the kinds of questions that I was hoping when I came here would be addressed. I have not heard too many definitive answers on this. Everyone is being too nice. I have no problem asking those questions. I would hope as a fallout

from this that each of you will consider them. I hope, first, that you will find that they have merit and are worth your consideration and second, that you do give them consideration and feed back in and close this loop so that we have spent our time profitably.

## Manufacturer's Overview

Edward W. Stimpson  
President, General Aviation Manufacturers Association

The General Aviation Manufacturers Association appreciates the opportunity to appear on this symposium for several reasons. We are interested in new ideas that are going to improve aviation safety. We cannot afford to close our minds to the introduction of new concepts; we are here to learn, to listen and to take suggestions and ideas back to our companies and to evaluate their feasibility. To my knowledge, this is the first time since GAMA was formed that government, industry, and users have gotten together on safety issues in a university environment.

I think Roger Winblade, Director of NASA's new Office of General Aviation Technology, put it very aptly the other day when he said that if NASA's work did not eventually reflect itself in product development, there was little point in NASA conducting programs. Roger's statement is a good guideline and is applicable to aeronautical research and development outside of NASA.

Today, general aviation provides a practical mode of transportation for getting the right person or right thing to the right place at the right time. The general aviation transportation role of moving people and cargo efficiently and conveniently is increasing, both in the United States and throughout the world, and is the most basic reason behind the industry's growth. It is estimated that general aviation carried one-third of the 250 million total air passengers carried in the United States during the past year. Sixty percent of the passengers carried in general aviation airplanes travel between points where there is no airline service.

This year, GAMA's members, who account for 99 percent of the general aviation airframes, engines, and avionics manufactured in the United States, will deliver approximately 14,000 airplanes with a value of over 800 million dollars. Over 3500 aircraft will be exported with a value of over 225 million dollars, and this is a substantial contribution to our balance of payments.

Safety is the keystone to the utilization and acceptance of general aviation. Transportation by general aviation would cease to be viable if it were plagued by accidents.

The accident rate in general aviation is improving. All of us want to see the rate continue in the downward trend. Last year, nearly 1000 fewer accidents occurred than in 1968, despite the fact that flying was up more than 20 percent over 1968. It is of little comfort that more people are killed annually at grade crossings, in pleasure boats, or on motorcycles than in general aviation airplanes, but the comparison places the accident record in perspective. We must not and will not stand on past progress, but we will continue to advance the cause of safety.

We all appreciate the heterogeneous nature of the general aviation fleet and the types of flying that are involved. Over 120 models of aircraft are currently being produced by U.S. manufacturers ranging from light single-engine trainers to intercontinental jets flying at airline speeds. The types



of flying and the proficiency of those who fly vary widely. For example, the same model of a single-engine aircraft can be fully equipped to operate in high-density areas and flown by highly proficient pilots, while elsewhere, a similar aircraft may operate from a grass strip at 7000 feet altitude with a student pilot.

Today, I would like to review some of the current activities that GAMA is undertaking to help improve the general aviation accident record. While each of the manufacturers, of course, has its own program, my remarks are confined to some of those activities that are being undertaken on an industry-wide basis.

As you know, the National Transportation Safety Board's figures show that over the past few years, the pilot has been cited as a causal factor in over 80 percent of all accidents, both fatal and nonfatal. Weather has been the second leading causal factor, accounting for 35 percent of fatal accidents and about 20 percent of nonfatal accidents.

In response to these findings, GAMA has made an all-out effort to reach the general aviation pilot community through support of the FAA-General Aviation Accident Prevention Program. To do this, we encouraged GAMA dealers and distributors to hold FAA safety seminars and clinics. In addition, representatives of GAMA companies participated in many of these programs. We also helped publicize and promote the FAA effort. To encourage attendance, GAMA offered 103 prizes, topped by a \$30,000 airplane of the winner's choice. During the period of time that the program was conducted, June 1, 1972 to June 1, 1973, over 206,000 pilots attended 1600 safety clinics. However, the most impressive result was that during this program, the number of general aviation accidents decreased by 12% while the number of fatalities dropped by 5 percent. Meanwhile, FAA estimates that the total number of flying hours increased by 12 percent.

The FAA Accident Prevention Program may not deserve all the credit, but surely someone must be doing something right. I know that the winner of the \$30,000 airplane feels that he did something right by attending a clinic.

Another effort to improve flight safety is the Pilot's Operating Handbook standardization project now underway by GAMA. In the past, pilots' handbooks, whether they be called owners' manuals, operating manuals, or something else, have been criticized for lack of uniformity and for containing too much or too little information. Through a GAMA working committee of top industry safety personnel and test pilots, a specification for uniform pilot handbooks is being developed covering the scope, content, and arrangement. Excellent progress is being made on this project, and we firmly believe that an industry-wide standard for this handbook will be a safety asset to pilots everywhere.

During the past ten years, more than one million Americans have been issued student pilot certificates. The quality of instruction is becoming an increasingly important factor as a growing number of people learn to fly. The manufacturers have introduced new and improved pilot training programs leading to private, commercial, and instrument certificates. New programs to improve the proficiency of those already flying are being implemented in conjunction with FAR Part 61. These programs, as well as efforts long

underway by the Aircraft Owners & Pilots Association and other user organizations, are showing positive results. We believe that the overall effect of the new improved training programs will be an improved safety record.

Because weather is a major factor in accidents, GAMA is working in concert with other general aviation associations through the General Aviation Associations Committee to develop long-range objectives and definitive requirements for improved weather information. In the near future, these proposed requirements, which will be presented to the National Weather Service, the FAA, and other government agencies, hopefully will result in action being taken to provide more useful weather information to the pilot.

Leaving the pilot aside for a moment, I would like to comment on the latter two parts of the man, machine, and environment triangle as they affect safety. We cannot expect aeronautical R&D to provide all the answers or solve all the problems. There is a need for R&D in both the vehicle and operating environment as neither is a mutually exclusive key to reaching the goal of improved safety.

Much is being done to improve the operating environment. The Airport/Airway Development Act of 1970 is providing the mandate and the funds to modernize and improve the airport/airway system. Although we may question certain actions that are taken from time to time, the fact is, we have the finest and safest airport/airway system in the world.

The general aviation aircraft that operates in the national aviation system is a product of proven design. It is a reliable and accepted product that has been subjected to extensive government supervision during its design, manufacture and operation in the system. The general aviation aircraft of today is one that has been thoroughly tested and constantly evaluated, and is one that has demonstrated high reliability. It has undergone a series of continuous refinements in all phases to increase safety of flight.

A major goal of the industry is to reduce mechanical malfunctions and increase reliability. Careful design, operation within approved limits, and proper maintenance are all necessary to reduce mechanical problems. The manufacturers are stressing all three areas to attain the best possible reliability and have such programs underway. In fact, a major design goal is maintenance accessibility. A number of these programs will be presented by general aviation manufacturers during the FAA Maintenance Symposium this December in Washington.

Manufacturers are cautious to implement new ideas until they are thoroughly proven. In no way do we want to compromise safety. This is well illustrated by GAMA's concern over the emission standards recently promulgated by the Environmental Protection Agency. While we are in agreement with the objectives of the EPA to enhance and improve the environment, we cannot agree that actions should be taken that in any way compromise safety. We have expressed our concerns to the EPA and the Department of Transportation, and hopefully some of these questions will be answered by research which is now being conducted by FAA and the industry. The whole area of noise and emissions lends itself to fruitful research and is an opportunity for significant contributions.

Whether an idea is developed by an individual, a company, a university, or a government agency, we are faced with several necessary constraints when considering its adoption and implementation. These are:

1. We must not only think an idea is good, but we must prove to ourselves and to FAA that incorporation of the idea will result in a product that meets or exceeds FAA minimum standards. The end result must be that the customer has a better product. A totally new design takes from five to seven years for development and certification and enormous capital commitment.

2. Any change in design must pay for itself through greater efficiency, greater utility, or improved reliability.

3. We must stand behind every product we manufacture. This means we must be satisfied that the device is safe and reliable and will not introduce more problems than it solves.

Like most industries, research and development are important to the future growth of the general aviation industry. A company cannot expect to survive in today's world if it is not developing new techniques and new products. This applies to the engine and avionics manufacturers as well as to the air-frame companies.

Earlier, I mentioned the work that is being done in the area of noise and emissions. This is only one of many fruitful areas which lends itself to innovation. The challenges presented by the energy crisis, for example, open the way to find new technologies and alternative fuel sources. The whole question of communications between the pilot and the ground, and the dissemination of weather information present more challenges. The challenge of developing the air-traffic control system to handle the VFR pilot as well as the IFR flight in the same air space has not been completely resolved.

Seminars like this, which stimulate dialogue on new ideas, are very important to the future growth of general aviation. We are glad to be here and will certainly take the ideas presented back to our membership.

**DISCUSSION - SESSION IV**

**PROSPECTS FOR AN IMPROVED SAFETY RECORD**

John Brennan  
Executive Vice President  
U.S. Aviation Underwriters Inc.

I have had a thought running through my mind for the past day and a half as I've listened to the presentations and the give and take from the audience, but I could not quite put my hand on it until last night ... it relates to a cartoon caption by the late Walt Kelley, the creator of the comic strip "Pogo." The caption read, "We have met the enemy and they are us."

The reason this thought keeps going through my mind is simply this ... I have attended numerous aviation industry meetings of this type ... Bar Association meetings ... trade association meetings, etc. They all share certain commonalities ... studies are held, committee meetings take place, we all vow to do this and that, and we say that this is a complex problem which does not lend itself to simple solutions. This is not true ... and we all know it! So, I am going to direct a couple of comments to the various participants at this meeting which, hopefully, will stimulate some basic improvement in the direction of aviation safety.

Number One - Aviation trade press. About two months ago, I attended an Aerospace Writer's Association meeting in Las Vegas. F. Lee Bailey was scheduled to appear on the program but was unable to make it and I sat in for him. Toward the end of the session which was on aviation product liability, a young man in the audience stood up and asked a question along this line: I work for an aviation magazine and our bread and butter is the advertising that the manufacturers place with my publication. How can I objectively write a piece on an aircraft and its operation and tell the truth?" I think that is a rather remarkable statement. I also think it is indicative of a lot of things that are wrong with this industry; and perhaps with this country. We lack candor. We are afraid to talk about things. We have a story to tell, but we don't tell it well. We choke up. We hide. We create committees.

The aviation trade magazines are a prime example of this attitude ... they say one thing on their editorial pages and then go on to fill the rest of their publications with less than critical pilot reports and unctuous pap about the joys of flying. Some of the ads are just atrocious. For example, we see a light twin sitting on a plateau in a mountain meadow. Grouped around the aircraft are six or seven people along with golf clubs and baggage. The impression is that everything in the picture, with the exception of the mountain, can be placed aboard the aircraft, along with a reasonable amount of fuel, and can be safely transported to some distant Shangri-la.

We know this cannot be done! There should be a meeting of the minds with Ed Stimpson and the members of GAMA regarding this matter. Advertising should do more than attract customers - it should inform and above all be accurate.

Number Two - FAA. Yesterday we heard Don Kemp go through the litany of general aviation accident causal factors. We have all heard the same

things before ... the standardization of cockpits, the location of knobs, gear handles, dials, and what have you. But what is done about it? Take a simple thing like the connection of the fuel selector valve to the fuel gauge on the instrument panel; I don't know how many lives have been lost due to fuel mismanagement. What about the status of service bulletins and airworthiness directives? Why don't we tell the owner of the aircraft more about the "why" behind a service bulletin or AD, rather than following the ritualistic, technical document approach? When there is a dispute as to whether an airworthiness directive should be issued, should not the rule be to issue the AD? In other words, when in doubt, send it out. To improve the overall safety record, the FAA must focus more of their attention on these items which are properly within their jurisdiction.

Number Three - Insurance Companies. We should all make a stronger effort to keep the unsafe owners and operators out of the sky. We can check and see if a pilot in fact is licensed as his application indicates and we should put more emphasis on his time in type and current flying experience, rather than his ratings and total hours, etc. Let's expend as much effort on engineering to prevent accidents as we do on engineering policy wording to deny loss coverage. There should be more investigations that spotlight the cause of an aircraft accident rather than just assess the resulting damages. A stronger and more professional underwriting approach on the part of the insurance industry can make a considerable contribution to aviation safety.

Number Four - Manufacturers. Why don't you tell the customer what the aircraft can't do as well as tell him what it can do? Why don't you tell the customer that in fact the specifications and performance statistics you publish are drawn after an experienced test pilot has flown the aircraft ... not the average pilot. Put out more information on the aircraft. Tell the public what to expect. Don't just prohibit spins but tell the pilot why he should avoid maneuvers that might result in a spin and furthermore, what to do if the aircraft gets into a spin. We could spend hours discussing the subject of notice since it is one of the fundamental concepts in our jurisprudence. People talk about rather complex defenses in today's sophisticated legal climate but there is a simple defense that is rarely used now which had its origin in the early days of the common law in England. It is called "assumption of risk" and has notice as its essential element. The rule briefly stated is that if the plaintiff consents to take his chances of harm from a particular risk created by the defendant, he is held to have assumed that risk and this bars any recovery by the plaintiff in a cause of action in negligence. In every case, however, it must be shown that: (1) the plaintiff recognized and understood the particular risk or danger involved (scienter); and (2) voluntarily chose to encounter it.

It is a fact that what I don't know might kill me and I think you will find that the flying public will still buy your product if you tell them more about it. They are interested in that product. They want to know how to safely maintain and operate it. They don't need additional sales propaganda.

I hope you haven't found these brief comments to be too caustic and I trust you feel the suggestions offered are simple and inexpensive. Another

thing that has been going through my mind at this meeting refers to a song my youngsters have been singing that goes something like this: "Today is the first day of the rest of your life." If you approach life on that basis and if we leave this meeting with the idea that each one of us is going to do something constructive to save someone's life, I think we would have something going. But we better not hide behind theories, committees and additional studies for if we don't do something now, the courts are going to do it for us. And we just might not like their solutions to our problems.

Lawrence P. Greene  
Assistant for Aeronautical Research & Development  
Department of Transportation

I am not going to say anything new. I feel that there are a number of points that have come out of the previous discussion that I made notes on and I would like to summarize. Back in the days when I wore rose-colored glasses and looked at general aviation with the idea that it was going to be the second vehicle in every garage, I realized that the initial efforts I was involved in on the Navion produced a very flight and crashworthy aircraft, but not a very competitive one in the marketplace. It emphasizes the problem that the manufacturer has to address. We cannot ignore the market while developing a great airplane.

However, the attitude of complacency that has been referred to in several comments such as the pilot not paying attention to the weather, his fuel gauges and a few other things, also represents an attitude of complacency on the part of the manufacturers. What Ed Stimpson has just said about the new aggressive approach being taken is a welcome reversal of that attitude. But I am advocating some utilitarian improvements in the product lines and certain additional safety measures that will, in fact, cost money. It is a fact that to build better structures, to build a more responsive aircraft, to put the tail in a different place so you do not have a deep stall problem is costly.

I am involved in research and development. I consider that the R&D effort that has been done on behalf of general aviation is pretty spotty and most of it is a manipulation of rule of thumb. And we should do more.

I was very concerned about the impression I got, from an earlier discussion, that we should promote flying as fun. That continues the scarf and goggles society syndrome. I think that is something we should avoid.

We have over 140,000 aircraft in the general aviation population. We have more than two orders of magnitude more automobiles. We have a better total record in terms of people killed, but not in terms of rate. That is, the rate of fatalities per operation is considerably worse than with the automobile. Karl Bergey made a plea that the Department do the same thing in aviation that we are doing for the automobile by investing in an experimental safety vehicle. We are, much more, when you figure the Federal investment in aeronautical R&D specifically applicable to safety aspects is about ten times what the Federal Government puts into experimental devices for automobiles. In spite of this, it is still a small number compared to the rest of the activity in the Department.

I was pleased to hear what was said about improving pilot's handbooks, and I am glad also to hear what John Brennan said about putting "real" information in and making a self analysis. I think these points are very important. I am also very happy about the improved attitude towards proficiency in training. I started flying in the '20's. I got my license and I enjoyed it, and it was fun. I decided in the '40's and '50's that I could



not afford to maintain proficiency, so I let my license lapse. I do not like the fact that I do not fly, but I feel that it was the right decision to make. I wish more people would do that.

I have a real hangup on general aviation that is related to proficiency. Use and real utility of general aviation equipment is perishably low. Many private aircraft are not used more than 200 or 300 hours a year, less than one-tenth what a commercial aircraft is used. In order to make general aviation really survive and grow, I think we have to do things to increase this utility. My son-in-law operates an aircraft in his business, and I challenged him on the question of whether it was a "status symbol" or whether it was a utility vehicle. He decided, after he looked at it, that it was a status symbol and he sold his airplane and then leased one when he needed it. After developing a whole new approach to his business operation, he found that he was getting his utilization up to a point where, with proper equipment and an instrument rating, he could support an airplane again and he bought a better one. I think this is the way general aviation should work the problem. It is important that more people look at the vehicle on the basis of what they are going to do with it. Then perhaps we would end up with a better reception.

I am very unhappy that Dennis Tuck had to say repeatedly, "I hope we can do this," and "I'd like to be able to do this." Mr. Baker, I would say that we ought to do those things that will change the image of the "VIP flying society" in the general public's eye. We have competition for money. We have priorities to set in dealing with problems associated with 150,000 population compared to other things beneficial to millions.

Let me address the very nauseous aspects of the cost allocation study. The overall facts are clear. They can be contested in detail, but it is still clear that the cost of the aviation system is extreme, it benefits a few, and is left for the general public to support. We have to find a way to both reduce the cost and to increase the revenue from the system without destroying it or us.

Finally, there are problems allocating priorities. I would say to all that I am not sure that Dr. Cannon's office (Systems Development and Technology in the Office of the Secretary) can necessarily change the will of the Department concerning aviation. However, I will submit that not once has a general aviation manufacturer or a general aviation manufacturer's representative come into our office and advocated any positive move on the part of the Department in behalf of civil aviation. The impression is given that you would rather have us go away--so I will.

Jack R. Hunt  
President, Embry-Riddle Aeronautical University

First, I am going to harp on the same thing you have heard me harp on before and I am going to keep harping on it until Ed and his friends get something done about it, and that is single-engine fuel systems. By the time they write up the accidents, it does not say what happened. What happened is that somebody got up there and got in trouble and the first thing he thinks about is the fuel system because it is so complicated and he thinks he had better get on it. If he is in any general aviation single-engine airplane, even if he were a contortionist, he would have cramps by the time he tried to find out where these knobs were and which way to turn them. So by the time he gets all of the wrong things out of his system, he has crashed. That is a big problem and we hope that you will continue to work on this thing and get it squared away to help us.

The Russians have a system -- I think it is a philosophy. I would like to espouse this particular philosophy. First, I thought it was a little backwards, but their attitude is that if it works, it is good enough. I think we can get to a single airplane fuel system that does not have all these knobs and it is good enough.

You are talking about the education problems. We are working all the time trying to do a better job of professional education. We work with what we call the amateur or the private pilot, but we really work for the professional pilot. But the friendly aviation agency will not allow us to work as professionals like anybody else in the academic area. We have to go to Part 61 or 141, or this or that, and do the things the 1400 and 2200 other people have to do instead of coming out like a professional who is training another professional such as a lawyer or someone similar and say, "Look friends, if your program is good enough, if the program can stand up, then these people ought to be given a license and we do not have to have somebody ride around and show them what a good instructor they were by being a check pilot."

If we could get a little help on that -- and I am talking for all higher education in aviation professional training.

The other thing is the enforcement of these pilot licenses. As nearly as I can tell, there are two types of pilots in existence today in the United States that are proud of their licenses, proud enough to show them. That is the guy that just got his private license and the egotist that has everything on his license, a jack of all trades and master of none. There is no enforcement system before the accident, only after the accident. I say to you, if we could get a system -- and it is relatively simple -- Hertz can do it, American Express can do it, if we would get an imprinter and your license says what your qualifications are at that date before he files that flight plan instead of after, we will do our job in training because these guys are going to come to us.

Roger L. Winblade  
Manager, General Aviation Technical Office  
NASA Headquarters

I would like to briefly discuss several points that have been raised during the last two days. The first, is the subject of relevance. How do we as researchers, government, university or private make our work more relevant to the field of general aviation or, for that matter, should the researcher even be concerned with the final application of his work.

Most research and technology programs, at least in the government, are justified and receive funding based on some projected end result, such as increased safety, greater performance, increased utility, etc. Before any of these objectives can be achieved, the results of the research must pass through the long and difficult series of compromises that describe the design, development, manufacturing, certification, marketing and service of a commercial product. Often the constraints and requirements posed by this cycle are more stringent than the problem that was the objective of the research effort. For research to be relevant, that is to proceed toward a real solution to a problem, the constraints posed by the application must be reflected back to definition of the research undertaken, just as the requirements specify the problem being addressed.

A very real constraint that must be considered in research and development in the field of general aviation is cost. There is one motivation for all of civil aviation, and that is to market either goods or service at a profit. Those companies that do not make profit do not long exist. Consequently, ideas or concepts that they attempt to introduce will again not achieve our objective of increasing safety because they will never go into the field. They won't be built, they won't be bought, and they won't be used.

I will leave that and address another point that was raised earlier. What kind of consideration do we give the average general aviation pilot? The response from several people was, what is the average general aviation pilot? In a broader sense we, in fact, know precious little about the entire general aviation environment. It is essentially uncontrolled and undocumented. When the manufacturer builds an airplane, he knows what the predominate use of the airplane will be, but he cannot predict what the specific individual who buys the airplane will do with it. I would like to briefly describe several programs that are aimed at just that, documenting the general aviation environment.

The first, as shown in Figure 1, is an attempt over the long term to identify the structural loads environment. A number of airplanes in all categories of use have been instrumented with the owner's permission. Periodically data from these recorders, the velocity, g's, and altitude time histories, are removed and returned to us. Statistically this will determine the loads environment for all categories of operation. We have currently amassed over 150,000 hours of data.

As shown in Figure 2, in this program we are attempting to identify how average people who fly airplanes approach, flare, and land, again on a

statistical basis. We are taking average pilots and trying to record them in a way that will least affect the data. Two instrumented aircraft have been returned to routine rental operation. We try as unobtrusively as possible to record approach and landing performance.

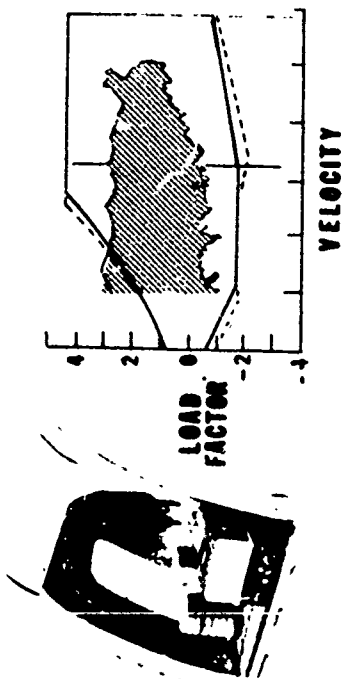
The third area has to do with traffic patterns around uncontrolled airports. The mid-air collision in terms of fatalities is probably not that significant if you balance just total numbers. The significance may show up more pointedly in the two bills I believe are still in Congress that could impact everyone because of the additional equipment required. About two years ago, the general aviation program gained access to a profitable tracking radar. This radar was taken to several general aviation fields where airplane type, weather conditions, and what the airplane did was recorded. We have some 3,000 tracks and for the past year, we have been cataloguing the data. We are now reaching the point of being able to go into the data base and work with it. I have two pictures that I will go through very rapidly to give an indication of the kind of things we have seen.

Two typical ground tracks are shown on the top of Figure 3. The tracks have been arbitrarily adjusted in time so that they would coincide at the threshold of the runway, implying a mid-air collision. We then worked backwards through the tracks, computed the relative position of one airplane to the other, superimposed this position on the cockpit field of view. We were then able to determine the percentage of time during those full patterns that one airplane could physically see the other, not that did, or would detect it, just that he physically could see it.

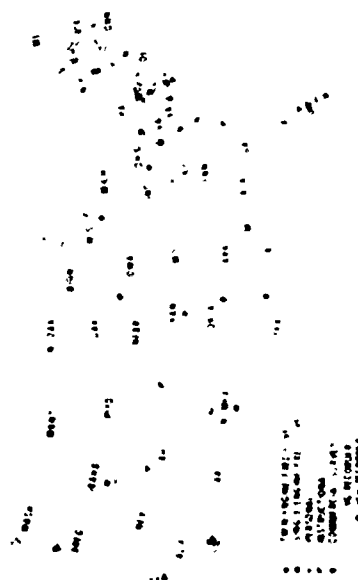
In Figure 4, we have plotted time to threshold versus range. The X indicates the periods of time that airplane B could not physically see airplane A and vice versa with the letter O. As shown, from approximately 90 seconds until the hypothetical collision neither airplane could physically see the other. That time corresponds to the turn on base leg. The detection would have to occur well before entering the pattern. To dispel the high wing low wing conflict, these were both the same type airplane, both high wing. It is only an example to emphasize the point that we still do not know enough about the general aviation environment.

# GENERAL AVIATION STRUCTURAL LOAD SURVEY

## INFLIGHT STRUCTURAL LOADS



## LOCATION



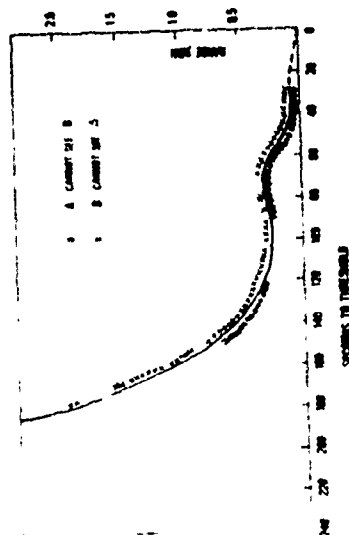
## TYPES OF FLYING

- TRAINING
- RENTAL/CHARTER
- FLYING CLUB
- PERSONAL TRANSPORTATION
- CORPORATE TRANSPORTATION
- PIPE LINE PATROL
- FOREST PATROL
- FIRE FIGHTING
- FISH SPOTTING

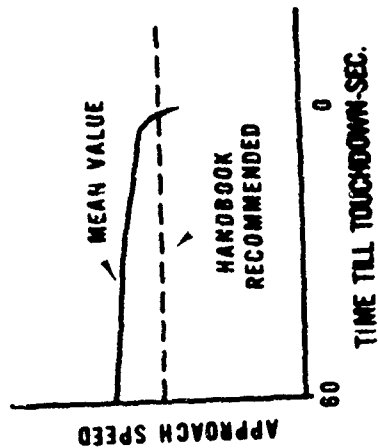
Fig. 1

# STUDY OF OPERATIONS NEAR AIRPORTS

Fig. 4



CONFLICTING AIRCRAFT IN VIEW



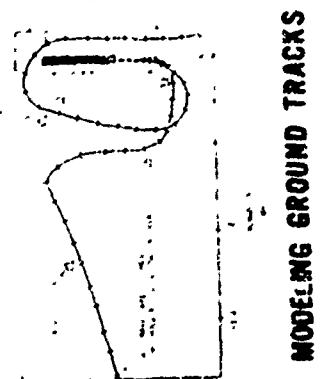
NASA RA 74-2037 (2)  
2-11-74

Fig. 2



Fig. 3

AIRCRAFT VIEW ENVELOPES



MODELING GROUND TRACKS

APPROACH AND LANDING TECHNIQUES



UNCONTROLLED TRAFFIC FLOW

QUESTION: Going back to the manual, the question came up as to the readability of the manual as the finished product, and you are not at this time interested particularly in word-by-word FAA approval, are you? Is there any thought given to a standing committee in GAMA to review the manual as proposed by the various manufacturers as a central clearing agency rather than allow each manufacturer to go ahead and use his personal words so that you get more standardization yet in the manual?

ANSWER: Not that far. I would hope that such would be unnecessary, that we would agree to these general standards being set down and they would be followed.

QUESTION: I have worked with three types of manuals: military, which gives the pilot everything he needs to know. In the commercial air transport business, the manual is a legal document required for the airplane and gives all the performance information. The operator manuals in general aviation, for the guy who needs it the most, are totally inadequate in describing the performance, the characteristics of the plane and things like this. In the area of the legal requirements we see people in the commercial market being somewhat concerned about legally writing out words that our airplane is not too good, so you ought to watch it. Does anyone have any comment on that?

ANSWER: You ought to put everything in the manual, and you should present it in a way that people can understand it. Somebody from the class of intended users should review the manual. The analogy I would like to make is something that was a prevailing business philosophy five years ago, certain ten years ago and before, that a manufacturer would not investigate an accident. He didn't want anybody from his shop at that accident, because somebody might think there was something wrong with that aircraft. Now we have the development of consumerism and product liability law so that if you don't go out there now, a couple of years hence you are going to be hit with a tremendous lawsuit. In the meantime, there might have been three or four more accidents coming out of that same generic problem. There has been a change in motivation primarily and unfortunately because of the economic consequences of not doing it. The same analogy applies. People misuse the law. They are concerned about what they do, and they shouldn't be. If they do things with the right motivation, our society will accept it. The coverups and the things done to avoid responsibility, etc. is the thing that has got too much of American industry in trouble today.

QUESTION: In many industries today, there seems to be an over-riding concern and even fear of the problem of product liability. The thought has

been expressed that the fear of product liability may to some extent be inhibiting the implementation of new technologies, even increased safety technology. Is that true?

**ANSWER:**

You have stated it very well. It is a problem. I think it is true in the drug industry and in a number of places. It might be analogous to the environmental question where we might not have a pipeline from Alaska if we had not had this energy crisis. It is a question of putting things in balance. This country has always over-reacted to things, and it is just a question until somebody gets enough information on the subject to put it back in focus. I do not know what the answer is, but the thing that is rather depressing is that too many people who are good thinking people have a dual set of ethics. They are a pillar of virtue in their own community, but when they go to the job, be it in the government or the commercial world, they wear a different hat. They think they have to wear that hat, and it is a very defensive hat. They will not answer a question. Nobody talks to the press. Anything I do I am going to be subject to criticism for. When you end up with a society of that type, you are going to face some rather severe consequences. How long it is going to take for that balance to be once more achieved is anybody's guess. I think that the law development cannot go much further. Simply stated, if you do have a defect today, regardless of anything else and of the fact that it might not technically be considered unreasonably dangerous if defective, you will be liable.

**COMMENT:**

Last year, we were engaged in a very serious one-sided exchange with the Office of Management and Budget. There were cutbacks and terminations in the aeronautical R&D area, many one-sided. This year, the President has wisely decided that he is sending Roy Ashe up the hill to talk to the various committees personally with the various associate directors. It still comes to the point you made of how a government allocates its resources. This is just an example of how the government makes statements on resources. As he and his people respond, "If you want more resources, something has to be given up." That becomes the crux of the problem. One might say the accident rate in general aviation is far less than those in farm machinery. This kind of problem has to be looked at in the overall context. It took NASA four years of rather insistent pressure on Congress to establish the office of general aviation. This reflected within NASA top management concern whether general aviation was a legitimate responsibility of NASA. Yet the appointment of this office does not necessarily mean a commitment of major resources. Just taking a quick look at the 1974 budget of NASA, roughly 3 billion of which, about 10% is for aeronautics. Out of that, \$300 million for aeronautics is included all in-house salaries



plus contract money. So the resources problem is acute and this suggests that we cannot look forward to large amounts of R&D money for solving general aviation problems. These need to be systematically pulled together so that we can all see what can be done based on the very limited number of dollars.

**COMMENT:** That is an accurate portrayal of the situation we are confronted with, and there is a quid pro quo in that if you add resources somewhere, you have to make the hard judgement where you are going to cut somewhere else. In assessing the priorities and particularly with the budgetary process we have which extends over several years before it comes to fruition, we have to identify and set our priorities clearly early on and start educating both in the macrocosm as well as the microcosm in the sense that we have to convince the other competing people within-house that theirs should be cut and this should be expanded and bureaucrats fight like tigers when that happens.

**GREENE:** There is a tremendous amount of money going into highways, specifically more than through NHTSA into the vehicle. They are putting a tremendous amount of money into concrete and roadways and signpost, etc. So are we putting it into the FAA into the operating systems.

**MILLER:** I talked to the cost allocation people for several hours when this was put together. I asked the question, "Are you equating the dollars that you are charging up against aviation for the air traffic control system against the dollars that are set up for the road system in this country?" and the answer was, "No. Why should we?" I thought that was a pretty bad answer.

**GREENE:** It is a bad answer but the problem is in the charter. They were chartered by Congress to do a specific task which was not necessarily to relate it to a dollar total but in fact to assess the cost.

**COMMENT:** Quantifying the relevant things is a real problem we have had in aviation. In the past, we have not been forced to do this. We are clearly in a new environment, particularly in Washington. It is the era of the cost benefit analyst and we are seemingly ill-equipped to quantify many of the end products from our activities. As a result, we are not as effective an advocate as we should be. I will pin that indictment on us and the FAA equally and with the same generosity apply it to everyone in here. We have done a very ineffectual job of convincing the American public and/or the decision-makers in Washington -- that we have a contribution to make, that it is worthwhile to spend public resources, and that we can justify every penny we spend on a quantifiable basis.

**COMMENT:** We do accumulate service difficulty information on military vehicles that are offspring of civil airplanes and use it in our assessment of service difficulties. We also published in 1972 a summary of crashworthiness information for light airplanes. In that, we have researched the crashworthiness information that has been developed by the military.

**COMMENT:** I have heard product liability blamed for the lack of communication between the general aviation manufacturers and the residents who are working. Is the product liability situation such that manufacturers cannot put in a handbook what is wrong with the airplane for fear of being sued because that characteristic of the airplane led to an accident, or is there an incentive to put in the handbook that this deficiency exists so that the public has thus been warned and they are not liable?

**ANSWER:** In so far as my company is concerned, if we knew of a product that we insured that was defective in some form or that there was information that should be put out to the public concerning that product and if that manufacturer did not choose to do so, we would no longer have any relationship. I suggest that in the course of accident investigation and in the insurance company's relationship that, if the insurance company comes across information where it can be stated with some degree of certainty that there is a defect and that the manufacturer is taking no steps to recall the product or to advise the users of the defects then it may be incumbent upon that company to report the information to the government or the public at large or suffer the consequences. This is the direction we are going. The reason that some people would not put some information out before was the possibility of product liability lawsuits. They would think that if they put this information out now and had 30 accidents over the past three years, then somebody who is a clever plaintiffs attorney is going to get that data and put it all together and we are going to be sued. If you are sued, then you have to recognize the probability and be prepared to protect your company's interest.

**COMMENT:** The system is set up now when there are defects discovered through manufacturers' reporting to FAA, to the whole AD notice system, through the manufacturers' bulletins directly to their customer, the system is pretty well established when defects are discovered. Every airplane has its operating limitations which should be noted in the manual of operations.

**COMMENT:** This is a specific example. Suppose that a particular model has only a small amount of stall warning the manufacturer of a military airplane would put it in the handbook and say, "Watch out,

fellows," and the pilot feels protected. He knows what to look for and is not overly concerned about it. If I were a manufacturer and I put that in my handbook and then got sued by everybody who had a stall-spin accident because of this deficiency, I would not tell them anything.

COMMENT: The whole purpose of the operating handbook obviously is to state the limitations of the airplane and its operating characteristics.

COMMENT: But you don't say that, and I have been told repeatedly that product liability inhibits the manufacturers from stating the situation as it really is. Is this true? Does the manufacturer pick up additional liability by putting into the handbook for the airplane, not defects in the sense that an AD would be required but things that the pilot ought to watch out for because that in combination with other things that might happen to him could lead to an accident?

ANSWER: Yes, to the point that the handbook is related to product liability cases. There is no secret about that.

QUESTION: What can we do about that?

ANSWER: That is why we are trying to get the very best handbooks and the very best information to the pilots.

QUESTION: Is the manufacturer picking up additional liability by doing it right?

ANSWER: I don't think so.

QUESTION: What can we do about this?

ANSWER: No manufacturer puts up with defects in his aircraft when they become known, or any component in the aircraft. I have heard the word "defect" a lot in the last few days. When you get a product improvement, you incorporate it. Every handbook that I have read incorporates advice to the user and operational limitations. The problems are generally created by ignoring the operational limitations and/or resort to the handbook only as a final and last resort.

COMMENT: One of the problems is that anyone with a military background looks to the pilot's operating handbook the same way that he did to a -1, and you don't find the same kind of material. If you are smart enough, you go out and explore the airplane yourself in a safe environment to find out what parameters you can operate safely within because, in my judgement, the handbooks in the past at least oftentimes left tremendous voids even for the competent, well-qualified pilot. I thought there was something a little

insidious in one part of your response, and that was product improvement. Oftentimes those product improvements could, in fact, be the correction of a defect. On occasion, we will have a problem show up, and John's comment was that to retroactively concede that if there were a problem, it can stimulate litigation, or at least be a great aid to someone to start a litigation.

**COMMENT:**

In going through the list of classes of people who have attended this meeting, I think I left out the academic community and I want to redress that right now. First, we talk about defects. I think we should call them alleged defects. My point with respect to the academic community is this. A great deal of the problem we have in product liability today is due to people who get on a stand and testify as experts to some of the wildest suppositions in the world, and that is part of the problem. "This could have happened." Sure, and people will buy it because you have 16,000 degrees and you come across as a pillar of knowledge from the tower of ivory.

**COMMENT:**

I think we have to redress past sins, and I had it brought home to me very strongly within the last month. I was going to fly a Citabria and take some people with me after I had flown the airplane. It appalled them that I wanted to see the handbook before I flew the airplane. They thought that was a concession on my part that I obviously was not as smart as all pilots were supposed to be. These are people with certificates. But if using the handbook is looked upon in the hinterland as a sign of weakness or fear, we have serious educational problems to overcome.

**COMMENT:**

This is a very good project. The specification will provide a way for all manufacturers to measure the same thing in the same terms and present it in the same place in the same handbooks. There is a great deal in there in terms of warnings, trips, operating procedures, notes on limitations of the airplane, an emergency section, but the guts of it is in performance. The performance will be realistic. It will be in knots. It will provide for taxi, for climb, for cruising at various powers, for some reserve when you get there. The book has been worked on by the safety people and the test pilots of all manufacturers, and it is a very good job. The next step as soon as they look at the third draft, it will go to various people for comment -- AOPA, NBA, MPA, FAA, schools and others. Is this usable from a pilot's viewpoint? I think you will find all the limitations in there, and if you fly the airplane according to this new handbook, you have simply exceeded the limitations if you get into problems.

**QUESTION:**

Is it the intent that the manufacturers will supply a new handbook for their existing aircraft types?

**ANSWER:** That is still an open question. Right now, we are shooting at new handbooks as they are written. Right now, we are trying to develop the specifications of what is the best method of presenting handbooks to average pilots and it is being looked at in that light.

**COMMENT:** Regarding the handbook, you made a statement that you have the specifications laid down and terminated at that point. Has anybody the guts to make caution notations in their handbooks that said if, under certain circumstances, you exceed these limitations, you can expect to wind up on your back in one second flat, or some such comment?

**ANSWER:** Yes. We have provision for a safety section which would apply to nearly all airplanes. Where do you put things like wake vortices? What can happen to you if you are flying behind the DC-10? -- How far do we have to go, I don't know. I quite agree with a remark that was made earlier regarding airplane characteristics. How an airplane operates is not necessarily a defect, but if you know how it operates, you won't get yourself in a compromising position. We want to get the information out so that the pilots will know what the airplanes can do, such as how they operate and what are their limitations.

**BAKER:** How do we get these handling quality improvements into airplanes in the fleet now, the simple ones, the obvious ones that don't require a rebuild, etc.?

**JIM RAILES:** In those areas where we were probing into concepts, the manufacturers either didn't have knowledge of or didn't have time to obtain the information to resolve the problems. However, NASA found it propitious that Roger Winblade's office be established and work to develop new technologies in order to integrate what a lot of us realize are improvements in the state of the art. This is one of the greatest contributions that NASA is making right now. If I may go back to something Lawrence said earlier. After all is said and done, we have a free enterprise system, and if you have a product that is deficient you are eventually going to go broke trying to sell it if nobody buys it. There is a new series of products that come out on the part of the big manufacturers that speak to better safety and such organizations as Robertson and others will have people come to their door to incorporate these safety features.

**JIM BEDE:** We have gone through a great number of things yesterday and today. There are a couple of things that we find ourselves faced with in two different areas of market. One is where we have a home-built airplane where we sell material and plans to amateurs to build their own airplanes. This becomes an interesting thing from a product liability viewpoint because we are really not the

manufacturer. The individual owner has to qualify for amateur-built status by doing over 50% of the work himself. This leads you into a lot of design problems. Just how do you design something that he isn't going to build wrong or build unsafely because either way, legally or just from a prestige standpoint, it can cause us a great deal of harm. So we spend a great deal of effort in our design philosophy on how we can prevent the amateur from doing anything wrong. We use 23 as our basic guideline and understand it to be a minimum. The area most frustrating to us is in taking our amateur-built version and converting it to a production-line version. We have essentially no regulations to meet. We have no real requirements to meet. It is amateur-built. It is experimental. It could be designed for 2-1/2 G's ultimate load. If the FAA inspector in the field feels that 2-1/2 G's is too weak, he can ground it. From a designer's standpoint, this is fabulous. For example, the airplane is completely riveted together, a common and ordinary type of construction. However, we do know of an adhesive that we have used for quite some time that is about 1/3 as strong as the epoxy adhesive but it is real easy to work with. It is not sensitive to surface conditions. An amateur can easily work with it. So we automatically tell him to put it on all his joints. But when we got the certification end of it, we had to rule out the adhesive because it is a real big job to prove that the adhesive will fit the structural needs that are in the material specs of the airplane. So it is economically required in our case to eliminate the adhesive from the production version when we can easily incorporate it on the amateur-built version. There are a number of things along these lines that we can do.

**Appendix I****LIST OF ATTENDEES****GENERAL AVIATION AIRCRAFT SAFETY CONFERENCE****OCTOBER 24-25, 1973****ORGANIZATION****REPRESENTATIVE**

Aircraft Builders Counsel, Inc.  
35 DeForest Avenue  
Summit, New Jersey 07901

James Palmquist

Aircraft Owners & Pilots Assoc.  
Washington, D.C. 20014

Ralph F. Nelson

Aircraft Owners & Pilots Assoc.  
Packard Bldg.- 12th floor  
Philadelphia, Pennsylvania 19102

Alfred L. Wolfe

Aircraft Safety Consultants  
2504 Webster Street  
Palo Alto, California 94301

Brent W. Silver

Air Facts Magazine  
110 E. 42nd Street  
New York, New York 10017

Robert Stangarone

Air Force Flight Dynamics Laboratory  
Wright-Patterson AFB, Ohio 45305

Robert J. Woodcock

Air Progress Magazine  
437 Madison Avenue  
New York, New York 10022

David Noland

American Jet Industries, Inc.  
2800 Clybourn Avenue  
Burbank, California

James Raisbeck

Analog Training Computers, Inc.  
121 Monmouth Parkway  
West Long Branch, New Jersey 07764

Judy Meltner

A. R. A. P. Inc.  
50 Washington Road  
Princeton, New Jersey 08540

John W. Olcott

Associated Aviation Underwriters  
90 John Street  
New York, New York 10038

Robert E. Breiling

## Appendix I

| <u>ORGANIZATION</u>  | <u>REPRESENTATIVE</u>             |
|--|-----------------------------------|
| Avco Lycoming Division<br>550 S. Main Street<br>Stratford, Connecticut 06497                 | Max Bentele                       |
| Avco Lycoming/Williamsport Div.<br>652 Oliver Street<br>Williamsport, Pennsylvania 17701     | John D. Edmunds                   |
| AVEMCO Insurance Company<br>7070 Old Georgetown Road<br>Bethesda, Maryland 20014             | Jerry A. Shrout                   |
| Aviation Consumer Magazine<br>Pan Am Bldg., Teterboro Airport<br>Teterboro New Jersey 07608  | James Holahan<br>Bally Tully      |
| Bede Aircraft, Inc.<br>Newton Municipal Airport<br>Newton, Kansas 67114                      | James Bede<br>Web Moore           |
| Beech Aircraft Corporation<br>1825 K Street, NW, Suite 711<br>Washington, D.C. 20006         | Nicholas Kuzo                     |
| British Civil Aviation Authority<br>5108 Marlyn Drive<br>Washington, D.C. 20016              | Laurence S. Edwards               |
| Business & Commercial Aviation Magazine<br>One Park Avenue<br>New York, New York 10016       | Richard Aarons<br>Archie Trammell |
| Calspan Corporation<br>Buffalo, New York 14221   | Robert P. Harper                  |
| Cessna Aircraft Company<br>Wichita, Kansas 67201   | Mike Owen<br>Bruce E. Peterman    |
| Canadian Ministry of Transport<br>Aviation Safety Division<br>Ottawa, Ontario Canada K1A 0N8 | P. D. Saunders                    |
| Detroit Diesel-Allison Division, GMC<br>P. O. Box 894<br>Indianapolis, Indiana 46209         | Melvin W. Byers                   |
| Dynamic Science<br>1850 W. Pinnacle Peak Rd.<br>Phoenix, Arizona 85027                       | S. P. Desjardins                  |



## Appendix I

### ORGANIZATION

Department of Transportation  
Office of the Secretary  
400 7th Street, S. W.  
Washington, D. C. 20591

Department of Transportation  
Transportation Systems Center  
Kendall Square  
Cambridge, Massachusetts 02142

Embry-Riddle Aeronautical Univ.  
Daytona Beach, Florida 32015

Environmental Protection Agency  
401 M Street, S. W.  
Washington, D. C. 20460

Federal Aviation Administration  
800 Independence Avenue, S. W.  
Washington, D. C. 20591

Federal Aviation Administration  
2100 2nd Street, S. W.  
Washington, D. C. 20591

Federal Aviation Administration  
P. O. Box 20636  
Atlanta, Georgia 30320

Federal Aviation Administration  
NAFEC  
Atlantic City, New Jersey 08405

### REPRESENTATIVE

Lawrence P. Greene  
John H. MacKinnon  
Robert L. Maxwell

Robert H. Reck

Jack R. Hunt

George Kittredge

John L. Baker  
Donald E. Kemp  
Gustav E. Lundquist  
George S. Mercer  
Howard E. Murphy  
Vance L. Oakes, Jr.  
Edward Podolak  
Edmund W. Sellman  
Herbert H. Slaughter  
Dennis A. Tuck  
David H. West  
Edward C. Wood

Joan B. Barriage  
P. Frank Castellon  
John K. Foster  
Bernard A. Geier  
Spencer S. Hunn  
Richard A. Kirsch  
Patrick E. Russell  
Colin G. Simpson  
Jerome Teplitz  
James F. Woodall

Don C. Jacobsen  
Robert T. Smith

Louis M. Allen  
George P. Bates, Jr.  
William Hanley  
Wayne Howell  
Joe Jaglowski  
Anthony Severino  
Roman M. Spangler

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ORGANIZATION

Federal Aviation Administration  
P. O. Box 25  
Moffett Field , California 94035

Federal Aviation Administration  
Federal Bldg., JFK Airport  
Jamaica, New York 11430

Flight Safety Foundation  
1800 N. Kent Street  
Arlington, Virginia 22209

Flying Magazine  
One Park Avenue  
New York, New York 10016

General Aviation Manufacturers Assoc.  
1025 Connecticut Avenue  
Washington, D. C. 20036

General Research Corp.  
Westgate Research Park  
McLean, Virginia

Grumman Aerospace Corp.  
Bethpage, New York 11714

Grumman American Aviation Corp.  
318 Bishop Road  
Cleveland, Ohio 44143

Haight, Gardner, Poor, & Havens  
One State Street Plaza  
New York, New York 10004

Hamilton Standard  
Division of United Aircraft Corp.  
Windsor Locks, Connecticut 06096

Hawthorne Associates  
Scotty Acres  
Angola, Indiana 46703

U. S. House of Representatives  
Committee on Science & Astronautics  
Washington, D. C. 20515

Univ. of Illinois @ Urbana  
Institute of Aviation  
Univ. of Illinois-Willard Airport  
Savoy, Illinois 61874

REPRESENTATIVE

Barry C. Scott

W. F. Norton  
James G. Plackis

Gloria Heath

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Susan Crandell  
Robert B. Parke

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Dave Thomas

Jim Densmore

Fred C. Rowley

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Robert L. Alpert  
Carroll E. Dubuc  
Walter E. Rutherford

Bernard Gatzen

Q. J. Hawthorne

William G. Wells, Jr.

Jesse W. Stonecipher

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### ORGANIZATION

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1600 Arch Street  
Philadelphia, Pennsylvania 19101

Johnson & Higgins  
95 Wall Street  
New York, New York 10005

Univ. of Kansas  
Aerospace Engineering Department  
Lawrence, Kansas 66044

McCarter & English  
550 Broad Street  
Newark, New Jersey 07102

Univ. of Michigan  
Department of Aerospace Engineering  
Ann Arbor, Michigan 48105

Mississippi State University  
Aerophysics & Aerospace Engr. Dept.  
Starkville, Mississippi 39762

National Aeronautics & Space Admin.  
600 Independence Avenue, S. W.  
Washington, D. C. 20546

NASA-Ames Research Center  
Moffett Field, California 04035

NASA Flight Research Center  
Edwards AFB, California 23523

NASA-Langley Research Center  
Hampton, Virginia 23665

NASA-Lewis Research Center  
Cleveland, Ohio 44135

National Oceanic & Atmospheric Admin.  
800 Indiana Avenue, S. W.  
Washington, D. C. 20591

National Transportation Safety Board  
800 Independence Avenue, S. W.  
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### ORGANIZATION

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Washington, D. C. 20361

New Jersey Dept. of Transportation  
1035 Parkway Avenue  
Trenton, New Jersey 08265

North Carolina State University  
Mechanical & Aerospace Engr. Dept.  
Raleigh, North Carolina 27607

Ohio State University  
Department of Aviation  
Columbus, Ohio

University of Oklahoma  
Aerospace, Mechanical, & Nuclear Engr.  
Norman, Oklahoma 73069

Pacific Scientific Company  
1346 S. State College Blvd.  
Anaheim, California 92803

Parker & Company, International, Inc.  
99 Park Avenue  
New York, New York 10016

Piper Aircraft Corporation  
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Lawrence T. Ellis  
Varel D. Freeman  
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David C. Hazen  
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Stephen Kidd  
Robert Langridge  
George L. Miller  
W. Barry Nixon  
Akira Obata  
Courtland D. Perkins  
Edward Seckel  
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### ORGANIZATION

RCA Laboratories  
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Robertson Aircraft Corporation  
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Renton Municipal Airport  
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Safe Flight Instrument Corp.  
New King Street  
White Plains, New York 10604

Univ. of Southern California  
2702 Sparrow Circle  
Costa Mesa, California 92626

Swearingen Aviation Corporation  
P. O. Box 32486  
San Antonio, Texas 78284

Technology, Incorporated  
5405 Duke Street  
Alexandria, Virginia

Texas A&M University  
Flight Mechanics Laboratory &  
Aerospace Engineering Department  
College Station, Texas

U. S. Aviation Underwriters, Inc.  
110 William Street  
New York, New York 10038

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614 Frelinghuysen Avenue  
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