MINUTES OF THE AVSCOM HELICOPTER IFR CONFERENCE

Hosted By

UNITED STATES ARMY

AVIATION SYSTEMS TEST ACTIVITY

HELICOPTER INSTRUMENT FLIGHT CONFERENCE

30 - 31 January 1973

Edwards AFB, California

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HELICOPTER INSTRUMENT FLIGHT CONFERENCE
30 - 31 January 1973
Edwards AFB, California

ATTENDEES	COMPANY/ORGANIZATION
BG William Maddox	Dir of Army Avn
COL William E. Crouch, Jr.	HQ DA (DARD-DDA)
LTC William C. French	OACSFOR
CW4 Robert L. Hamilton	OACSFOR
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Mr. Robert A. Stange	AMC, CRD-FQ
COL John C. Geary	AVSCOM, AMSAV-E
Mr. Charles C. Crawford	AVSCOM, AMSAV-EF
Mr. Leonard L. Howard	AVSCOM, AMSAV-EF
Mr. Clemence P. Mudd	AVSCOM, AMSAV-EFD
Mr. Vasken A. Haroian	AVSCOM, AMSAV-EEA
Mr. Neal J. Donaldson	AVSCOM, AMSAV-EFA
Mr. James Hatcher	AVSCOM, AMSAV-EFH
Mr. Oliver W. Boynton	AVSCOM, AMSAV-EFT
Mr. Rodger L. Finnestead	AVSCOM, AAH-PMO
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Mr. J.F. Koch	AVSCOM, HLH PM
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MAJ John R. Smith	USAASTA, SAVTE-TI
MAJ Warren E. Griffith	USAASTA, SAVTE-TB
MAJ John R. Burden	USAASTA, SAVTE-TB
MAJ Roger W. Waddell	USAASTA, SAVTE-TA
MAJ Carl F. Mittag	USAASTA, SAVTE-TI
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1LT Marvin L. Hanks	USAASTA, SAVTE-TI
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Mr. James S. Hayden	USAASTA, SAVTE-CT
Mr. Richard B. Lewis II	USAASTA, SAVTE-TD
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Mr. L.D. Corliss	AMRDL/Ames
Mr. Terrence D. Gossett	AMRDL/Ames
Mr. Robert P. Smith	AMRDL, Ft. Eustis
Mr. Joel L. Terry	AMRDL, Ft. Eustis
Mr. Henry Kelly	AMRDL, Langley
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Mr. Eugene W. Levine	ECOM, AMSEL-VL-E
Mr. Otto Schoenberger	ECOM, AMSEL-VL-E
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Mr. Norris A. Servais	Astronautics Corp.
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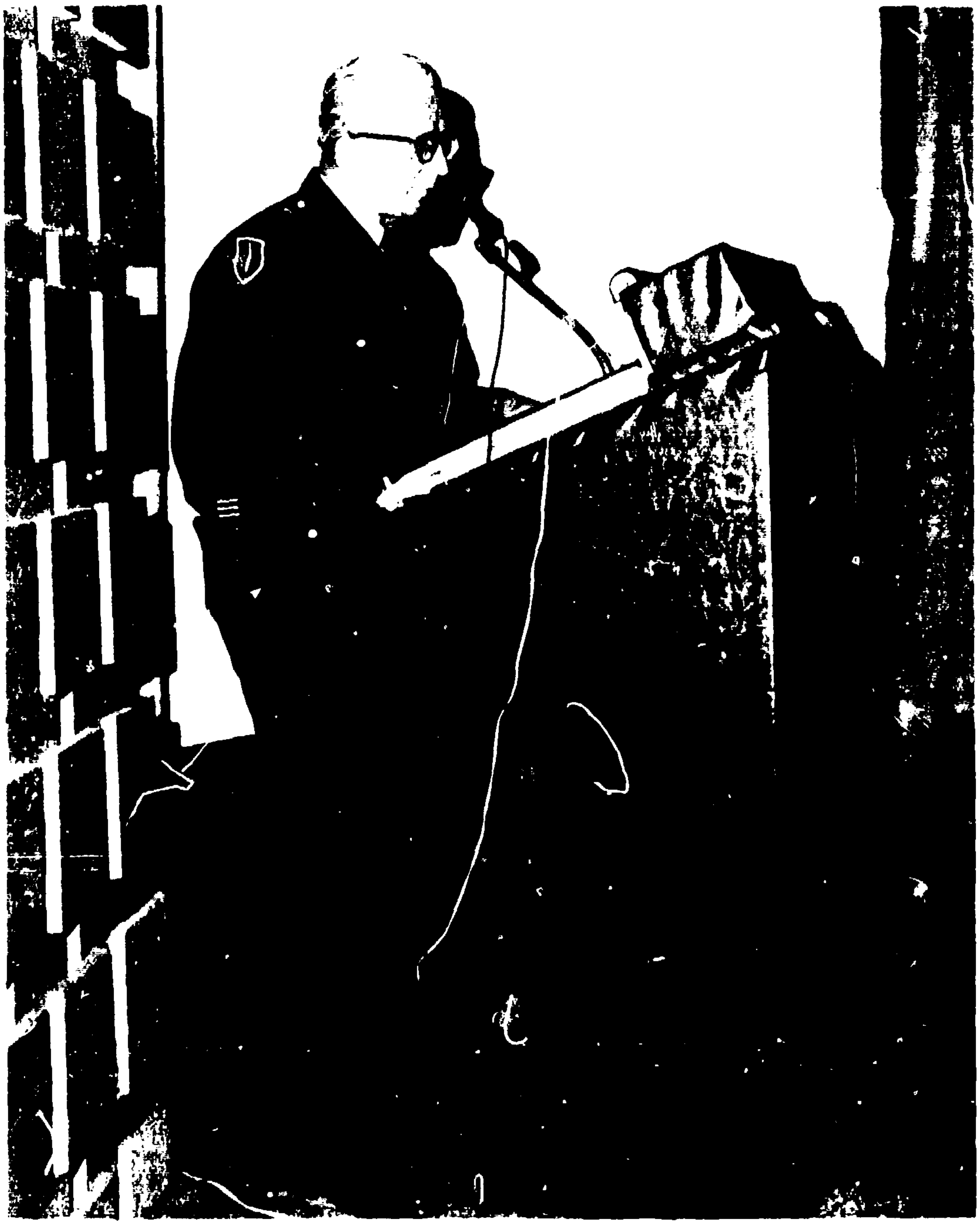
FOREWORD

We wish to express the appreciation of AVSCOM and USAASTA for your attendance at the AVSCOM Helicopter IFR Conference held at Edwards Air Force Base, California, on 30 and 31 January 1973. Your enthusiasm and cooperation helped make the conference a success and a very worthwhile endeavor.

The conference provided a means of bringing Army agencies, other government agencies, and industry personnel together to discuss the capabilities of Army helicopters to fly in instrument conditions, the efforts being expended to qualify these aircraft to fly IFR, and the future needs of Army helicopters to satisfy the IFR requirements.

Each attendee is being provided a copy of the minutes of the conference. Hopefully, these minutes will be beneficial as a reference in future helicopter development efforts. These minutes were recorded during the presentations and subsequent question and answer periods and are, within the capabilities of USAASTA, a near-verbatim reproduction of the proceedings. An agenda and list of attendees is also included for your use.

The participation and cooperation of US Air Force, Navy, and Federal Aviation Administration personnel and representatives of the helicopter avionics and airframe manufacturers, as well as the Helicopter Association of America, contributed greatly to the success of the conference. The use of the main ballroom at the Edwards Air Force Base Officers Open Mess and the excellent service provided by the mess staff in serving the meals and setting up of the conference room was greatly appreciated.



COLONEL JOHN C. GEARY
Director for Research, Development, and Engineering
US Army Aviation Systems Command

OPENING REMARKS

COLONEL JOHN C. GEARY
DIRECTOR FOR RESEARCH, DEVELOPMENT & ENGINEERING
US ARMY AVIATION SYSTEMS COMMAND

Good morning, gentlemen, welcome to the US Army Helicopter Instrument Flight Conference sponsored jointly by the US Army Aviation Systems Command, Flight Standards and Qualification Division of the Research Development and Engineering Directorate in St. Louis, and the US Army Aviation Systems Test Activity here at Edwards. I wish to thank all of you for your expressed interest as evidenced by your attendance here today. A special "Thank You" is extended to BG William Maddox for taking time from his extremely busy schedule to honor us with his presence. Finally, additional thanks is in order to the many individuals who have set up the conference and coordinated on all the accommodations.

The primary purpose of this conference is threefold: first, to provide to the interested agencies a general debriefing on the IFR testing that has been under way at ASTA. Included in the debriefing will be the test procedures we employ, the results completed to date, and the future tests planned to fully address the IFR problem. Second, other agencies have consented to provide us a technical survey on their test efforts, and from this, we will describe the overall technical needs for helicopter IFR flight as projected by the various agencies and commands. Third, and finally, to allow representatives from industry to describe their present hardware capability and recommend future requirements for both avionics and airframes.

The need for helicopter IFR flight is of sufficient importance to be discussed separately and will be covered thoroughly by General Maddox; so I will bypass that and only summarize the development of the testing process.

Historically, our review of IFR requirements for helicopters began as early as 1958. The H-19 was used to establish optimum cruise and approach speeds under IFR conditions and even a few zero-zero landings were experimentally conducted. Subsequently, the H-21 and H-34 were also flown IFR but our test methods were less formal in those days and many of the requirements that were derived were not documented. However, the experience of those earlier programs was reflected in several later efforts such as the JANAIR studies on vibration cues, motion effects, external visual requirements, and instrument complements needed for IFR. Today, the low level night operations study using the RAVE aircraft (Research Aircraft, Visual Environment) is another example of continuing research on helicopter flight under limited or low visibility conditions. Another aspect of our earlier development was that much of the airworthiness qualification testing of the Army's helicopters was performed by the other services. In other cases, the full range of tests covering IFR were not always required and to this extent we still do not have a clear definition of the IFR requirements for every specific aircraft in the inventory.

For example, the CH-47 was reviewed and qualified by the Air Force and, on the other hand, the UH-1 has not been thoroughly and formally tested for IFR qualification although the UH-1 has been extensively flown in IFR conditions. The increased need for IFR flight, coupled with a better capability of the airframes and engines to withstand adverse environmental conditions, has necessitated setting up more formal test programs with complete documentation to establish IFR standards. Mr. Crawford will provide an overview of the Army's present airworthiness qualification process. Also, the results of the tests on the CH-54, OH-58, OH-6 and AH-1 programs will be delineated in detail in each of the ASTA presentations.

I do not mean to imply that we now have an answer to all of the questions related to IFR. On the contrary, the discussions here today and tomorrow will hopefully assist us to be more encompasing and address areas of concern that heretofore have been neglected. This may be more readily evident when one considers that present Army regulations and FAR's do not discuss the quality and quantity of instruments, icing limits, engine ingestion maximums, and turbulence levels for IFR conditions, but only cite basic visibility and gross instrument minimums. The very nature of this conference is to expand on existing requirements, define new requirements, and to conduct more thorough testing to ensure that all of the requirements defined are analyzed and considered in the IFR qualifications process.

In conclusion, this conference will have served its purpose if it results in a better technical definition of IFR requirements, more comprehensive flight testing, closer technical contact between the agencies and industry, and an overall appreciation of the problems and magnitude of the airworthiness qualification process used by the Army.

Thank you for your attention. Now General Maddox, Director of Army Aviation, will give the keynote speech on the need for instrument flight.

BRIGADIER GENERAL WILLIAM MADDOX

Director of Army Aviation
OACSFOR

NEED FOR INSTRUMENT FLIGHT

BG WILLIAM MADDOX
DIRECTOR OF ARMY AVIATION

Thanks, John. I feel that I have been on instruments quite awhile here, inasmuch as I arrived at Los Angeles at 5 o'clock this morning after a rugged ride on the airlines. I came here not because I could afford the time out of Washington at this critical juncture with a new Congress coming together, a new secretariat which hadn't been named yet and a new administration in office. I came out because I had an intense interest in instrument flying.

I started IFR flying fairly early in my career because back in the early 50's I had several occasions to go inadvertent IFR in helicopters that had no instruments. Fortunately, in spite of the fact the helicopters weren't designed to do that sort of thing, we managed to work our way out of the clouds without a fatality.

I wondered whether we would be able to draw much of a crowd today to talk about this esoteric subject. I am gratified there is so much interest and hope it is not just because California is a great deal warmer than it is in the East. I don't know where we stand in this instrumentation program. I came into office about two years ago and one of the first things I said was, "We're going to have to face up to the Army's goal that we want to operate around the clock with near daylight, clear air efficiency," and I said, "Let's get some instruments on the OH's and Cobras and let's go out and fly instruments." I was told that this was too simplistic an approach. We had a lot of things that we had to understand.

I was reminded, when I looked at this program, of a comment made to me by the GE folks at Lynn, Massachusetts. They were explaining that there are six phases of any program. First is enthusiasm; the second phase is confusion; the third phase is disillusionment; the fourth is "The Search for the Guilty;" the fifth is "Find the Innocent;" and the sixth is "Award the Noncontributor." I am just not sure what phase we are in, in this program, but I think it is beyond innocent enthusiasm.

Speaking of the noncontributor, this reminds me of another story I heard recently about the home football team that was getting pretty bashed up by the visitors. In the fourth quarter, the score was 40 to nothing in favor of the visitors and the home guys finally managed to recover a visitors' fumble down in the visitors' 20-yard line. That was the first time they had been in the visitors' territory all afternoon.

So the coach said, "We've got to capitalize on this. Let's go for a touchdown; let's not get skunked." So he sent the quarterback in and said, "Now you get in there and you give the ball to Leroy." The quarterback went in there; he looked around at Leroy but passed the ball off to the right halfback who charged into the line. There was a great shattering of bones and spurting of blood; the halfback was on the ground and they hauled him off. So the coach sent a substitute in and said, "All right now, tell the quarterback to give the ball to Leroy." The new right halfback ran on the field and reported the instructions to the quarterback. This time the quarterback looked at Leroy and then passed the ball to the left halfback. There was another splintering of bones and the left halfback was hauled off.

The coach couldn't stand it any longer so he called time out to get the quarterback off the field. He said, "I thought I told you twice to pass the ball to Leroy." The quarterback replied, "Coach, I don't know how I can get this through to you, but Leroy say he don't want that ball!" So it is with the instrumentation business. We are faced with the problem of how to handle the ball whether we want to or not, so we might as well get on with it.

Now let me tell you about Lamson 719, which was the South Vietnamese incursion into Laos in the spring of 1971. The Vietnamese went in and set up fire bases and then those fire bases came under pretty heavy North Vietnamese attack. You remember they were in the North Vietnam home ground, so it was just a matter for the North Vietnamese to concentrate on each one of those fire bases and start picking them off.

We had troops of the 17th Cavalry who were working around Fire Base 31, which was up on top of a hill. The weather was getting bad. The gunships were working, knocking the enemy down as they were coming in under the wire. The weather started to come down lower. Next thing you know, tanks appeared right behind the enemy infantry. At that time the clouds completely obscured Fire Base 31 and all night long and the next day the weather was down. People inside the base were calling for medevac, resupply, fire support – all the normal things we do with helicopters.

Finally the people inside the fire base decamped, moved out; abandoned their equipment or destroyed what they could, and left.

It was a pretty stark story and it underscores dramatically the effect that weather and poor visibility conditions can have on your capability to do combat. Now, we are nowhere near the goal of being able to operate around the clock with near daylight efficiency when we have to back off in the middle of the afternoon saying, "We are sorry, we can't come out and work with you any more, guys. We must go home – the weather is too bad." The infantryman who has to be out there regardless of what the weather is, takes a pretty dim view of the part-time warriors who help him. If the helicopter can't stay with him and give him full-time coverage, then they lack the utility that he really requires.

In this Lamson action, there are two things that we're concerned with. One is to be able to continue to fight. The gunships should have been able to operate around that fire base regardless of the weather. Second, the air line of communication, medevacs, resupply ships should have been able to continue to go into that fire base, make a pinpoint landing, pick up and take off without being constrained by the weather. We're not to the point of being able to solve either one of these problems.

What are the sub-tasks to these problems? One is the ability to operate in low visibility; the second is the ability to operate in icing conditions. The third is to be able to operate at night when there isn't enough light. This involves the pilot doing his job on a navigation basis as well as a gunner or an observer being able to acquire and engage targets. Lastly, we put in the additional constraint, and that is that all of these tasks have got to be performed while the aircraft is operating low-level. This is a pretty stringent requirement. So there is the whole list of things that we really have to do.

Now, there are a few special considerations that I would like to speak to that apply to the Army aviator. I am sure you understand that we in the Army operate on a completely different philosophy from the other Services, and with good reason. We have different missions. In the Army we are concerned about giving the user the aircraft that he needs on a full-time basis. This automatically works out into a decentralized approach to the use of aviation. The company, battalion, or brigade commander who needs aircraft on a full-time basis gets them on a full-time basis. Our vehicles generally are in forward areas as a result. Secondly, we're a continuity force. We strive for full-time coverage. We don't have aircraft that are transient visitors to the battlefield. The aircraft operator is not tasked out for a single mission where he goes out, discharges his ordnance, and goes home. He is tasked for the completion of that operation. This means around the clock, in good weather and bad.

Now for the type of people we have. We do not have a constant-sized force with a good mix of experience on which to rely. Instead, we in the Army are subject to peaks and valleys in our manpower. For example, this year we are down to nearly 800,000 men in the Army. We are down from an Army that was 50 percent larger two years ago. This is a special consideration that you people who deal in hardware have to consider. When we expand for combat, we must train in large numbers. We have people – many, many people – going into combat with 250 hours flight time – some with even less.

Given our large strength fluctuation, I see no way in the future to give our workaday aviators a substantial amount of flying time before they are committed to combat. So we must design for the pilot who does not have a lot of experience.

Now let's talk hardware. As far as the helicopter is concerned, it is not like fixed wing aircraft. Let me emphasize the point that John Geary made earlier. We don't really know what our stability requirements are so that we can write a Mil Spec that will ensure that the average aviator can operate successfully in instrument conditions. This problem must be resolved soon. Then we will know what to do with the airframe.

We used to have an old philosophy that when you went on instruments – you did instrument flying – you went from point A to point B and came down. You heaved a big sigh of relief because you had cheated the odds again, and you spent the rest of the day watching the rain and hangar talking. Well, we are not able to do that when we operate as a continuity force and are required on the battlefield on a full-time basis. We will have to accommodate ourselves to flying instrument for awhile, then flying contact awhile, then flying instrument awhile. Most of our guys are flying combat 8 hours a day, but don't do it every day. We have had many, many pilots with 180 hours flight time a month. I have flown 200 hours in combat a month myself, but the cutoff where we would like to stop is about 140 hours a month. At any rate, recognize that people are going to be flying for long periods and we will have to accommodate the instrumentation for these people.

Some years ago, when the Air Force and the Navy went to an all-instrument force and started instrument flying on a regular basis, the pilots tended to divorce themselves from the terrain. I see this in Army aviators now. You ask them, "Where is your map?" You get in with them and they've got a map. It has little blue lines, and little blue compass roses, no mountains on those maps, no rivers, no terrain features at all, just strictly instrument flying maps.

Well, we can't have that in our business, because on a continuous basis, you go visual and you go instruments. We've got to organize so we do not divorce ourselves from the terrain, but have an instrument capability as well as a very sharp capability to operate on a contact basis.

We are willing in the Army to accept new training requirements based on the way you shape the cockpit, organize the instruments, and establish the displays. However, we must recognize that the job of the attack helicopter pilot and the job of a light observation scout or a slick driver in a transport are going to be different. At the same time, we don't want to degrade the capability of the pilot to do his normal visual job as we establish his instrument layout for him. Next, let's keep the cockpit simple. I should point out that what we show the pilot today probably is a lot more than he really needs. There probably are many of these large bulky instruments that are not necessary for the average pilot. It may well be that a warning light system is a simpler way to call his attention to his real problems.

If he is operating low-level, operating in low visibility, having to move his attention back and forth inside and outside the cockpit, we just cannot do justice to all of the information to monitor. We are finding that out in the night flying that is being done up at Hunter Liggett, in Northern California. These guys are flying at 50 knots with eyeballs at night, regardless of the light conditions, and they are able to do rather remarkable things at altitudes of 200 feet in the rocky Gavilan valley there at Hunter Liggett. That's right in the mountains, and at 200 feet the aviators are still able to do a good night's work on a visual eyeball contact basis, but they can't see all of those instruments all the time. We must look very carefully at what we really need in the cockpit. I'll conclude that the improved systems and techniques are lagging behind training. We're already well along in a training phase. By this coming summer or autumn, 99 percent of the Army aviators probably will have a current instrument ticket. We have done this in about the last 18 months. We are about 85 percent now and are pressing down hard to get the last 15 percent.

So I am doing my part to get the Army aviator capable of round-the-clock operation with equal or close to the capability that we have in the daytime in clear weather. Now I'd like to hear in the next two days what you people are going to do to help us out on the equipment side of the coin.

Thank you very much.

INTRODUCTION OF MR. CRAWFORD

COLONEL GEARY: Thank you, General Maddox. That sort of sets the guidelines as to what we need to be looking for. I just want to emphasize a few points about all-clear weather capability. During one short tour I had in Vietnam I had the chance of flying with the people who fly at night, the fire-fly operators. I went out with them several times. One of the pilots I went out with, during his tour had accumulated over a thousand hours of flight time and not one hour of that was in the day. He didn't know what Vietnam looked like in the daytime.

Also with regard to junior Warrant aviators, I have taken the opportunity to fly combat assault operations with some of these people and one day I was assigned as a crewmember on a Huey and my copilot was a W1 Warrant Officer. During the process of the day, we started exchanging notes and he said, "Sir, how long have you been flying?" I told him, and he said, "Boy! You've been flying longer than I've been alive." His closing comment was, "For an old man, you do pretty good." General Maddox did also say we are looking for something in terms of a meaningful instrumentation. The classic and minimum instrumentation occurred about 1957 in an H-13 in Thule, Greenland, when an H-13 helicopter was caught in a whiteout. The only instrument that pilot had for IFR operations was his compass. Now strange as it might seem, because it was a liquid-filled compass and because he could maintain the liquid level horizontal, he was able to successfully complete his IFR flight. Now that's just a bit more austere than we think we need, but to emphasize and tell you what we are trying to do and how we are trying to achieve our objectives, and how we are trying to get an IFR airplane that is capable of not just flying the airways and going from point A to point B, but to do a lot of the things that General Maddox says, Mr. Crawford, who is our airworthiness qualifier for the Army has a few comments. Charlie.

MR. CHARLES C. CRAWFORD

Chief, Flight Standards and Qualification Division
Directorate for Research Development and Engineering
US Army Aviation Systems Command

HELICOPTER IFR QUALIFICATION PROCESS

CHARLES C. CRAWFORD
FLIGHT STANDARDS AND QUALIFICATION DIVISION
US ARMY AVIATION SYSTEMS COMMAND

Thank you, Colonel Geary. My name is "Leroy" Crawford. Before I start my briefing I would like to make a public apology to the group on behalf of a gross misjudgment on my part. When we first tried to plan this conference, I did not envision the interest that industry and other government agencies have shown in this meeting. If I had, I want all of you to be assured that the American Helicopter Society would have shared a large portion of the thanks for conducting this particular conference. However, because of this misjudgment, it has not been announced in their name and I apologize for that particular group.

Colonel Geary indicated that the subject I would speak about is a brief introduction to you of the airworthiness qualification process used by the Army and how, in the future, we think it will relate to the qualification of helicopters for instrument flight operation. The first chart summarizes the Army's approach. For a lot of the Army personnel in the crowd as well as the prime manufacturers of helicopters, this message is going to be old hat for the first five minutes. However, in the interest of our friends from the Air Force and Navy and some of the avionics manufacturers who may not have gone through this process with us, I do want to present a brief review.

First slide

First of all, within the Army we are organized such that we have a central point for making technical decisions and for handling the responsibility for ensuring that our aircraft are, in fact, airworthy. In a practical manner this is a small engineering organization like an FAA that is located within Colonel Geary's Directorate of RD&E. We find this system to be an excellent balance between the pressures of the Army management and the Project Managers to get the aircraft out on schedule, between the contract folks to make sure that the terms of the contract are met and the practical consideration of making sure that the aircraft is, in fact, airworthy for our Army aviators to operate. The operational experience which causes us to concentrate on this point was very aptly explained by General Maddox in his remarks.

Secondly, we feel that to formalize this airworthiness process, we must start with uniform procedures to be used for all companies. There is no reason why Company A should be allowed to get by with a weaker or less stringent qualification program than Company B, and in order to make sure that these programs are comparable and that the demonstrations performed by industry are of equal rigor, you just have to simply work on your standardization. Some standardization in many senses can be painful; they can be particularly painful when you are trying to get a program approved with a budget that is less than adequate. On the long haul I believe it pays off, though, to make sure that all companies are treated the same in their demonstration of their aircraft to the military.

The third point essential to equal treatment is the preparation and incorporation into all Army contracts of an airworthiness qualification specification. This is the document that is designed to lay out in contractural terms, all the things that industry must do in order to ensure to the government or to the Army that the aircraft meets the systems description requirements. Finally, we establish an audit trail of what we've done so the proper guy can get fired when things go wrong, at the end of the program, by the publication of what we call an Airworthiness Qualification Substantiating Report. In this report we document all of the reasons for limitations on the aircraft. We have found that in the improvement of some of the current vehicles, particularly those that were developed by other services, we have found that the reasons for the limitations on the aircraft are not well known.

Looking at how these concepts are, in fact, implemented will give you the overall summary of the elements of an airworthiness qualification program. The approach is keyed to a systems safety effort because the main thrust of an airworthiness program is to ensure safe operation of the aircraft within prescribed limits. While specification requirements are a key part of this, emphasis must be on safety. We start out by running a systems safety program which is designed to uncover in the development of the aircraft all possible faults that could, in fact, endanger Army crews or the success of the aircraft in accomplishing its mission. Secondly, as the manufacturer goes through the development program, we have detailed design reviews and analyses. We accept the concept that many times, proof of compliance can be made much more cheaply by analysis than by test, so whenever this is practical, with austere financial arrangements, we use that approach. A mock-up is worth a thousand reports or a thousand analyses. Therefore our mock-ups are obviously a key part of the program.

In that regard, the Directorate of RD&E within AVSCOM has recently established its own mock-up facility. For our first particular project, with funds of the HLH Project Manager, we took on a big one. We are now building a cockpit mock-up of a heavy lift helicopter so we can perform within the government, without the overhead of the Boeing organization, independent studies of arrangements that we feel would optimize the aircraft and simplify the aircraft for purposes of coming up with the best possible HLH we can. This does not relieve Boeing of any responsibility whatsoever, but just gives the government the opportunity, with a little bit of hands-on engineering, to make our contribution and to make more meaningful suggestions from our organization as we go through it.

We also found that the existence of this mock-up facility is somewhat useful in the source selection process. Where we find we have a novel arrangement of an aircraft that is very difficult to evaluate by looking at the drawings, we build a little mock-up of what you are talking about and can decide whether it is good or bad.

The procurement process and specification play a key role in qualification and this effort is frequently overlooked. A manufacturer can go through the process of designing the soundest rotor drive shaft that you have seen, but if the material processes used in that shaft are not correct, the integrity of the shaft is not adequate. So we are trying to bring into our program more and more engineers in a material discipline in order to ensure that our designs are not only sound in design concept, but also from the material processes used in the manufacturing process.

Component tests speak for themselves. I'd like to cover system surveys and contractor demonstration in a little more detail in some future charts. Finally, the Army's role in the operation of the aircraft itself toward the objective of determining the proper flight envelope are the last two items on the chart. These tests, as you know, are those of an engineering nature and are done right here at Edwards. That is one of the reasons we wanted to have this particular meeting here.

The system surveys as we laid them out for helicopters are not necessarily "must pass" tests; they are just what they imply. They are surveys of some particular technical capability of the aircraft. For example, the first one I guess is classical, which is the flight load survey in which we required the prime manufacturer to go through and make a detailed in-flight loads measurement of the helicopter with the emphasis, of course, on the parts that rotate. From that information and certain ground tests, the fatigue life can be established. There are no particular "must pass" loads associated with this test. The loads that are encountered simply have a big effect on the allowable fatigue life.

This is a total list of surveys that are conducted and, I think, there are a couple of them that are pertinent to the IFR problem with special interest; the power plant surveys from a standpoint of icing and inlet tests are important and the lightning protection test and the complete environmental survey for icing at the very bottom. Those are the ones for which we feel we need to beef up our requirements now, if we are to ensure that the aircraft released to the field do have adequate IFR capability.

The contractor demonstrations are summarized on the next chart. These are "must pass" tests.

The flying qualities demonstrations are suited for the IFR problem and the avionics subsystems because the avionics installed are largely a function of the environment in which you are going to fly the aircraft. IFR has a big impact. This sort of sets the stage for how we go about qualifying an Army air item. I would like to continue with the impact that this approach has on IFR.

Next slide (slide 2)

The different considerations for IFR operations are: What are the flying qualities requirements? To what extent should they be more stringent than for VFR operation with visual references? I am not going into more detail on that because there is a panel discussion this afternoon that will address that subject in itself. The second additional consideration which the Army is concerned about, of course, is the crew station design and its impact on crew workload. Again, the work we have accomplished thus far in that regard will be briefed to you by the ASTA team, so I am going to skip over that.

The next one is the redundancy of design relative to safety and this is something we are working on because this redundancy is keyed to ensuring that if a guy is out in bad weather conditions and has a failure of some type within the airplane, that he is not committed to either necessarily terminate the flight or to an unsafe flight condition. On the other side of the coin are redundant electrical systems, redundant hydraulic systems, and in the case of two power plants, are expensive. Therefore, this redundancy is a trade-off consideration which we are looking at.

Finally, communications and navigations systems requirements are, of course, functions of operational environment which the aircraft will be operating under. They are different for CONUS; they are different for Europe.

Slide 3

This chart is designed so it cannot be read. Colonel Wright was going to provide field glasses for all of you to view this chart. However, it turned out that when he took his survey there were not enough Signal officers in the Army Test Activity, so we can't go that way. What this chart was intended to do is roughly compare for you the current regulatory status relative to equipment and the redundancy of equipment. By that we mean in some cases, two indicators or two altimeters, or two of this or two of that, indicating they have to be two to operate safely.

This is sort of an overall survey of where the Army stands on its regulations on equipment aboard for IFR. The second column is the Air Force and the third column on the right-hand side are Navy requirements; the three columns on the far right are FAA requirements for various categories of operation.

Slide 4

Going on to the next chart, this chart summarizes the types of ground navigational equipment that will be essential to our IFR operation for various elements of the world. The first would be normal CONUS operation, the second outside of the country – I think that chart was primarily tailored for a European combat environment.

Later on in some panel discussions, people from the Electronics Command are going to discuss what the Army plans to do with regard to improving the combat situation. You will note that the only major difference between CONUS and out-of-the-country is the use of a transponder at the bottom. Of course, this is a very common item in all our aircraft that operate in CONUS. It's not installed in all the aircraft, but is the only real key difference between in-country and out-of-country. There are many things, of course, that are not available for the combat side of the coin.

Slide 5

Going on to the next chart. Now you can tell, briefly, additional test requirements that we feel will be a part of future IFR test programs. The first one is some measure of the crew's workload. This is a quantitative check that we feel should be made early in the program to confirm that the types of equipment on board are satisfactory in order not to overload the workload of the flight crews, considering their main objective when they're flying IFR is to have them think about the war instead of thinking about the control and operation of the aircraft.

The people can only tell about how difficult it is, and how difficult it is to do this and how difficult it is to do that. But it is one area where we feel we are going to have a meaningful exchange with industry as to the quality of the aircraft; we must quantify this crew workload effort. Our first attempts at this are to be briefed in some detail later by the ASTA people so I'll just leave it at that point right now. However, if this test is to be meaningful, it must be done very early so that equipment changes that may result from high workloads can be made at a point where it will not be an economic disaster by making a physical change to an aircraft.

The second is a helicopter in-flight icing test facility. I'm going to cover that a little more in detail in a minute so let me skip over that particular point as to how we plan to demonstrate the adequacy of the aircraft in operating under icing conditions in a relatively safe environment. And the last point which is, of course, the simplest of the three, is to establish a program where actual IFR operations are made by military crews without the assistance of any contractor personnel before an aircraft is released for IFR operation by our troops. This is a very important proof-of-the-pudding type of test, particularly in the light of the relative difference of experience between normal combat operation Army aviators and the kinds of crews industry use to develop the aircraft; it is the difference between night and day.

Going back to the second point. We are developing an icing test system which we will operate from a CH-47C which creates ice particles for the test helicopter flying in formation behind the CH-47C. Of course, this icing condition can easily be eliminated by turning off the ice or by moving the helicopter out of the spray window. The concept of a spray rig is nothing new, but wondering how we were going to meet General Maddox's requirement for determining what helicopters would do under icing conditions as they stand today, we found ourselves in a hell of a mess.

The Canadians have a very fine facility for hovering a helicopter under a spray rig and which, if the wind happened to be blowing properly, you might get up to 20 knots forward speed. The Air Force had an equally useful facility on their C-130 spray rig that operates out of here at Edwards Air Force Base. However, this system is not really very useful below 100 knots and I think it's probably marginal below about 120 knots. What we are talking about is a range of 20 to 120 which is where the helicopter usually operates, so we found that we really needed to develop a new capability that would be peculiar to helicopter operation, and therefore, we had competition within industry for someone to develop this for us. A little bit about this in a dimensional sense is shown on the overlay. The width of the spray at the outlets of the aircraft is 75 feet. We have a design requirement in the spray rig specification for a window of two sizes. This particular chart only illustrates one size, which is the larger of the two. It is for a concentration of ice to meet certain specific dimensions, that will be 75 feet wide and 13 feet high. Now for larger concentrations of ice, the two outer sections are removed and you have a 24-foot wide icing cloud with roughly triple the concentration. A bit of information on the particle sizes; these are under the control of the flight crew of the spray rig helicopter and they can be varied from 15 to 50 microns and the density is also under the control of this crew and it can be varied from 2.65 to .85 grams per cubic meter. Now 2.65 is a good rain storm/ice storm and .85, of course, would be comparable to a light icing condition as far as density is concerned.

Slide 6

The next chart gives you a bit of a feel for physically how the thing works. However, you can see the thing operates from a large water tank inside which pumps water out into the spray area and the combination of the water coming out of the tank and the bleed air from the engine creates ice from an atomizer. Now the atomizers are located across the main bars and these locations are adjustable. One atomizer points up and one down for each location. This is the means that we use for getting the 13-foot-thick elevation of the cloud or height of the cloud. The width of the spray bar is 75 feet and there is some expansion of the spray as it goes back over the test helicopter. Future versions that we see might be possible for a real large helicopter like an HLH, might be a double decker of the thing, but right now our main objective is to make this system work.

Slide 7

A little bit of how the atomizer works is shown on the next chart. We have a water inlet here which flows around this particular nozzle and the air from the compressor bleed goes through the nozzle and the shearing effect where the two meet is the item that produces the droplets. The variables are, of course, the variation of the atomizer diameter at the outlet by positioning the thing up and down and, of course, the air flow rates and the water flow rates.

Slide 8

The next slide will give you a brief idea of what we hope the flight envelope for this particular capability will be from the standpoint of speeds and altitudes. The Chinook, fully loaded, would weigh approximately 40,000 pounds. With the full weight capability, we should be able to make runs up to 23 minutes with maximum icing emission from the rig and with the lighter weight condition, we can get a little higher altitude in case you need to for colder temperatures at just up to 11 minutes, but we feel that with those kinds of turn arounds at speeds that are shown here, we would have a useful test vehicle up to around 8,000 feet at the heavy weight, up to around 10,000 feet at the lighter weight. With slight dive of the helicopter, of course, the benefit of increasing speeds by 20 to 25 knots, is shown between the dashed lines which are power limits or transmission limits and the solid lines which is essentially the operational limiting dive speed of the helicopter. The schedule by which we hope to complete initial icing tests is shown on the next chart.

Slide 9

The hardward is here at ASTA now. However, there has been a delay in the test vehicle getting out here for maintenance reasons. The stuff was delivered by the end of December. We hope to have the aircraft here at ASTA by the 2nd of February. Instrumentation ready - everything ready to go by the 5th of March, with the spray rig installed by the 19th of March and we will have the operational testing done and qualification finished in order to know how to use the rig and ensure that the rig meets all the contractural requirements that we set up in the contract be done by the 20th of April. Then between May and November we hope to have tested all first line Army helicopters behind this particular rig to determine the level of icing that they can tolerate under their current configurations. Now when I say first line I mean, of course, turbine powered machines.

Unfortunately because the program has fallen behind schedule, due to unavailability of the mother ship, and a bunch of other things that we don't need to go into here, we may have to do this testing in Alaska rather than here at Edwards Air Force Base, but we envision a significant cost savings in the future by testing new helicopters behind this rig right here, which, of course, avoids the large cost of going to the Canadian area for the initial hover test, which has been the procedure in the past.

Slide 10

To summarize, we see that we need to firm our IFR requirements to a consistent level with other airworthiness requirements. In other words, the IFR program should be no different from any other aspect of qualification from the standpoint of our policies and procedures and how they qualify. This, of course, is not inconsistent with the fact that there is an awful lot of operational judgment that goes into whether an aircraft is really satisfactory or not. Rest assured that such requirements are adequate, but do not, in fact, gold plate the airplane.

General Maddox pointed out in his opening remarks that in many cases, we may really have too many instruments. The current emphasis on cost is such that we cannot allow that to happen so we've got to get the weather requirement, but we must be careful not to overstate it. And then we must expand our test programs to include flight under actual instrument conditions, including instrument conditions involving ice. We feel this can be accomplished in a safe manner by establishing prerequisites such as operation of the helicopter behind the spray rig before we do.

This concludes my portion of the presentation. I would now like to move on into the session in which ASTA will brief you on the results of some recent tests that they have conducted to evaluate the capability of some of our current aircraft for IFR operation. This testing, of course, does not yet include any icing conditions, just strictly visibility problems associated with IFR in that sense. To get this portion of the session started, I will turn the program over to Colonel Wright, Commander of ASTA.

ARMY APPROACH

- CENTRAL POINT FOR TECHNICAL DECISIONS AND RESPONSIBILITY.
- ESTABLISHED UNIFORM PROCEDURE FOR ACTION
- AIRWORTHINESS QUALIFICATION SPECIFICATION FOR SYSTEM DESCRIPTION AIRCRAFT.
- FORMAL AUDIT TRAIL VIA SUBSTANTIATION REPORT

SLIDE 1.

ADDITIONAL CONSIDERATIONS

- FLYING QUALITIES
- CREW STATION DESIGN AND CREW WORKLOAD
- REDUNDANCY OF DESIGN RE SAFETY
- COMMUNICATIONS/NAVIGATION REQUIREMENTS

SLIDE 2.

MINIMUM INSTRUMENT AND EQUIPMENT REQUIREMENTS FOR IFR OPERATION.

INSTRUMENT OR EQUIPMENT	MILITARY OPERATIONS REGULATIONS			FAA OPERATIONS AND DESIGN REGULATIONS (FAR'S PART 23, 27, 29, 91, 127)		
	USA AR 95-1	USAF* AFR 56-10	USN OPNAV INST3710.7E	IFR	CAT II**	HELICOPTER
AIRSPEED INDICATOR	1	1	1	1	2	1
ALTIMETER SENSITIVE	1	1	1	2	2	2
ATTITUDE INDICATOR	1	1	1	1	2	2
CLOCK, SWEEP SECOND HAND	1		1	1	1	1
COMPASS, MAGNETIC	1	1	1	1	1	1
FREE AIR TEMPERATURE INDICATOR						1
GYRO RATE TURN INDICATOR	1		1	1	1	2
HEADING INDICATOR	1	1	1	1	2	2
SLIP AND SKID INDICATOR	1		1	1	1	[illegible]
RADIO ALTIMETER					1	
VERTICAL SPEED INDICATOR	1		1		2	1
COMMUNICATION TRANSMITTER	1					2
COMMUNICATION RECEIVER	1					2
NAVIGATIONAL RECEIVER						2
NAVIGATIONAL ADF	1					[illegible]
NAVIGATIONAL VOR						[illegible]
APPROACH ILS					2	1
MARKER BEACON					1	1
IFF/SIF (TRANSPONDER)						
FLIGHT CONTROL GUIDANCE SYSTEM					1	
PILOT HEAT, EACH TUBE	1	1	1		1	1
POWER SOURCE, INSTRUMENT	1		1	1	1	2
POWER SOURCE INDICATOR (VAC)	1				YES	
STATIC PRESSURE SYSTEM					1	1
LIGHTS, INSTRUMENTS	YES					YES
LIGHTS, POSITION				YES	YES	YES
LIGHTS, LANDING				1	1	2
ANTICOLLISION BEACON	1			1	1	1
FLIGHT CONTROLS					DUAL	[illegible]
WINDSHIELD WIPER					YES	YES
WARNING SYSTEM, INSTRUMENT					YES	[illegible]

* ADDITIONAL INSTRUMENT AND EQUIPMENT REQUIREMENTS ARE SPECIFIED IN AIRCRAFT DESIGN SPECIFICATION AND OPERATOR'S MANUAL.

**CATEGORY II ILS APPROACH - MINIMUM DECISION HEIGHT 100 ft, RVR 1200 ft.

EQUIPPED AS APPROPRIATE

SLIDE 3.

GROUND NAVIGATIONAL AIDS

THE MOST COMMON NAVIGATIONAL AIDS IN BOTH CONUS AND THE COMBAT AREA, ARE:

AID	CONUS	OUT COUNTRY	COMBAT
VOR	X	X	
TACAN	X	X	
VORTAC	X	X	
DME	X	X	
LORAN C/D	X	X	X
NDB (ADF)	X	X	X
L/MF RANGE	X	X	
VHF/UHF DF	X.	X	X
ILS	X	X	
TACTICAL LANDING SYSTEM			X
RADAR	X	X	X
TRANSPONDER	X		X
FM	X	X	X

THE ARMY TACTICAL FM GROUND RADIOS CAN BE USED AS NAVIGATIONAL AIDS (HOMING) BUT DOES NOT PROVIDE DESIRED ACCURACY.

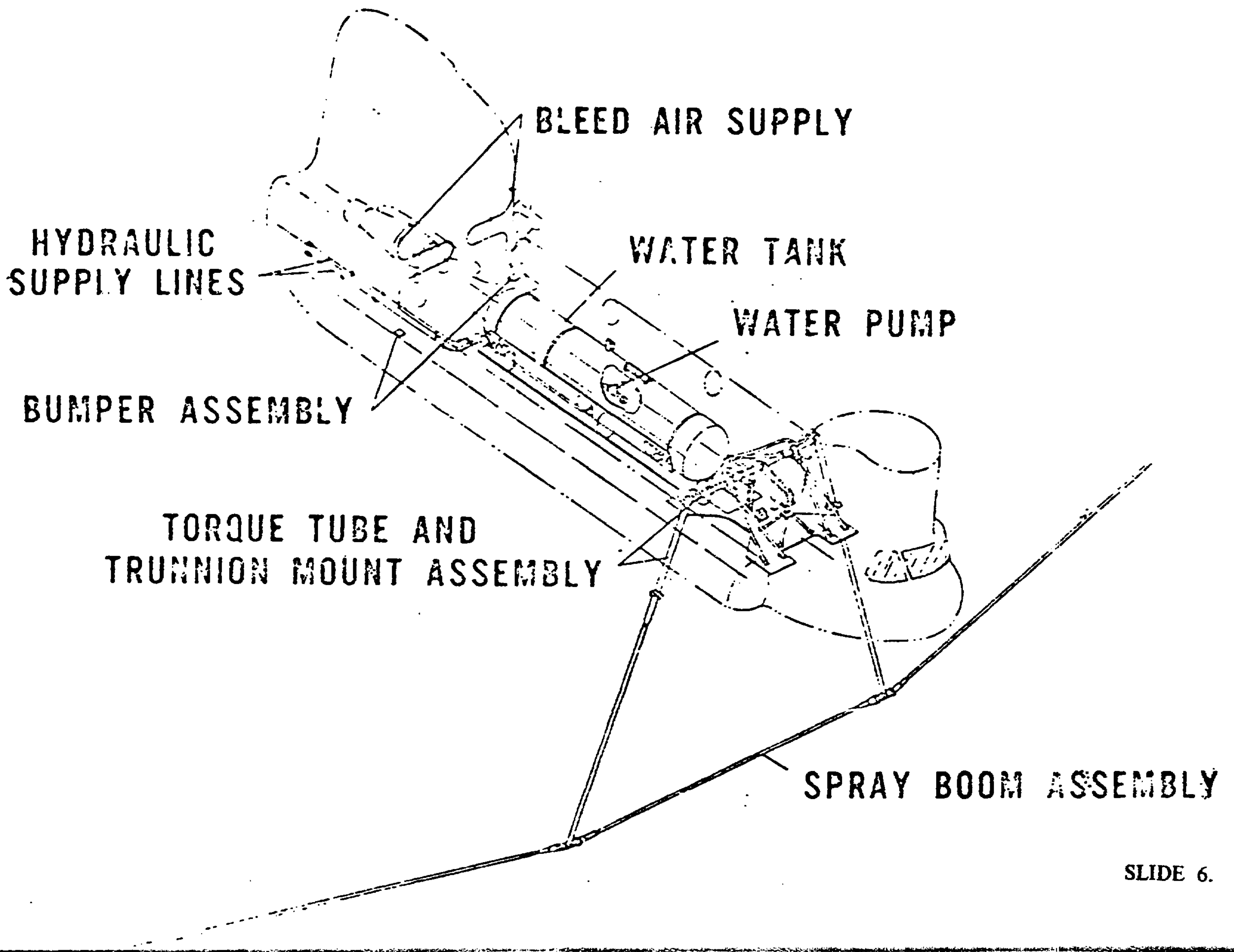
SLIDE 4.

ADDITIONAL TEST REQUIREMENTS

- CREW WORKLOAD
- HELICOPTER IN-FLIGHT TEST FACILITY
- ACTUAL IFR OPERATIONS

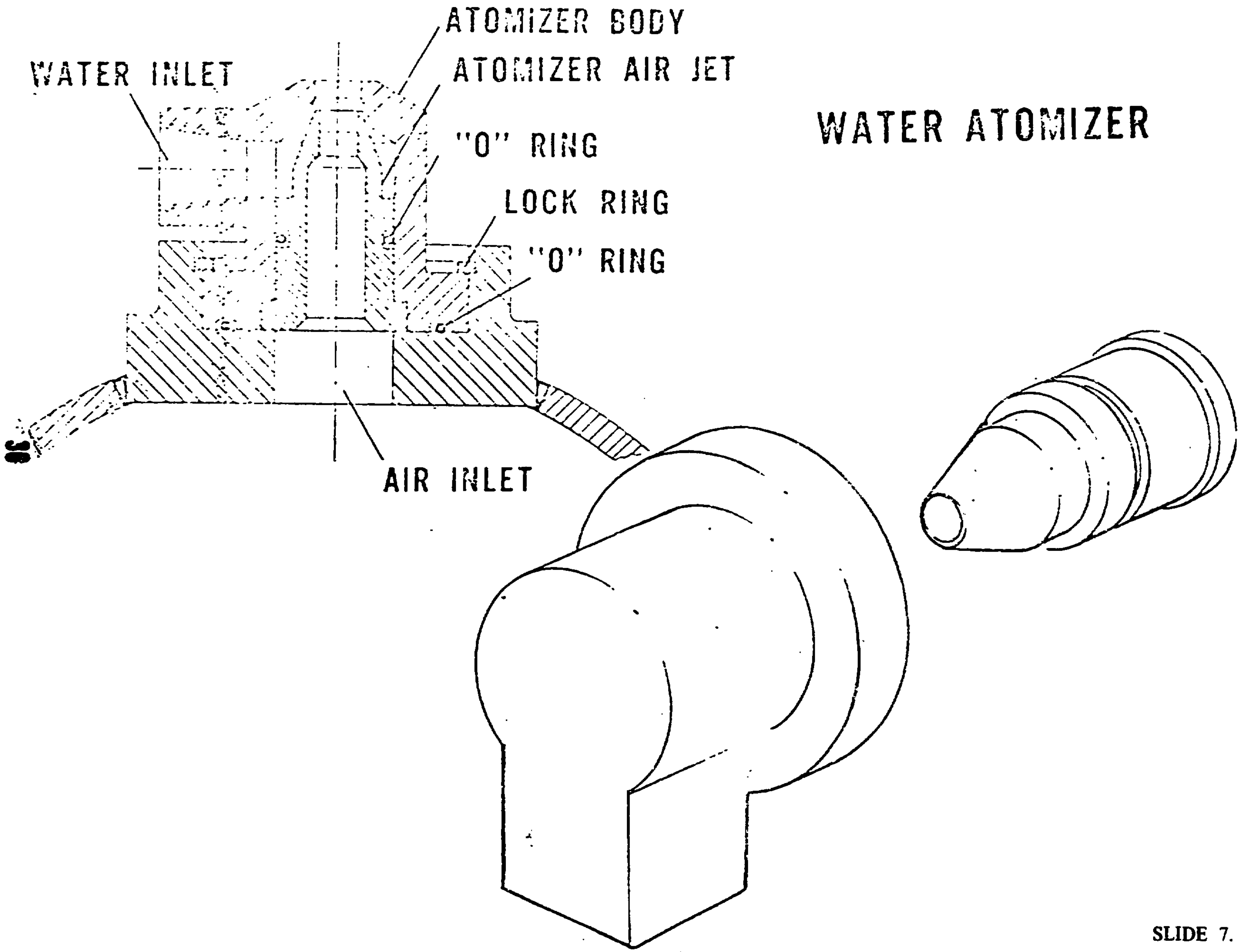
SLIDE 5.

SPRAY RIG HARDWARE



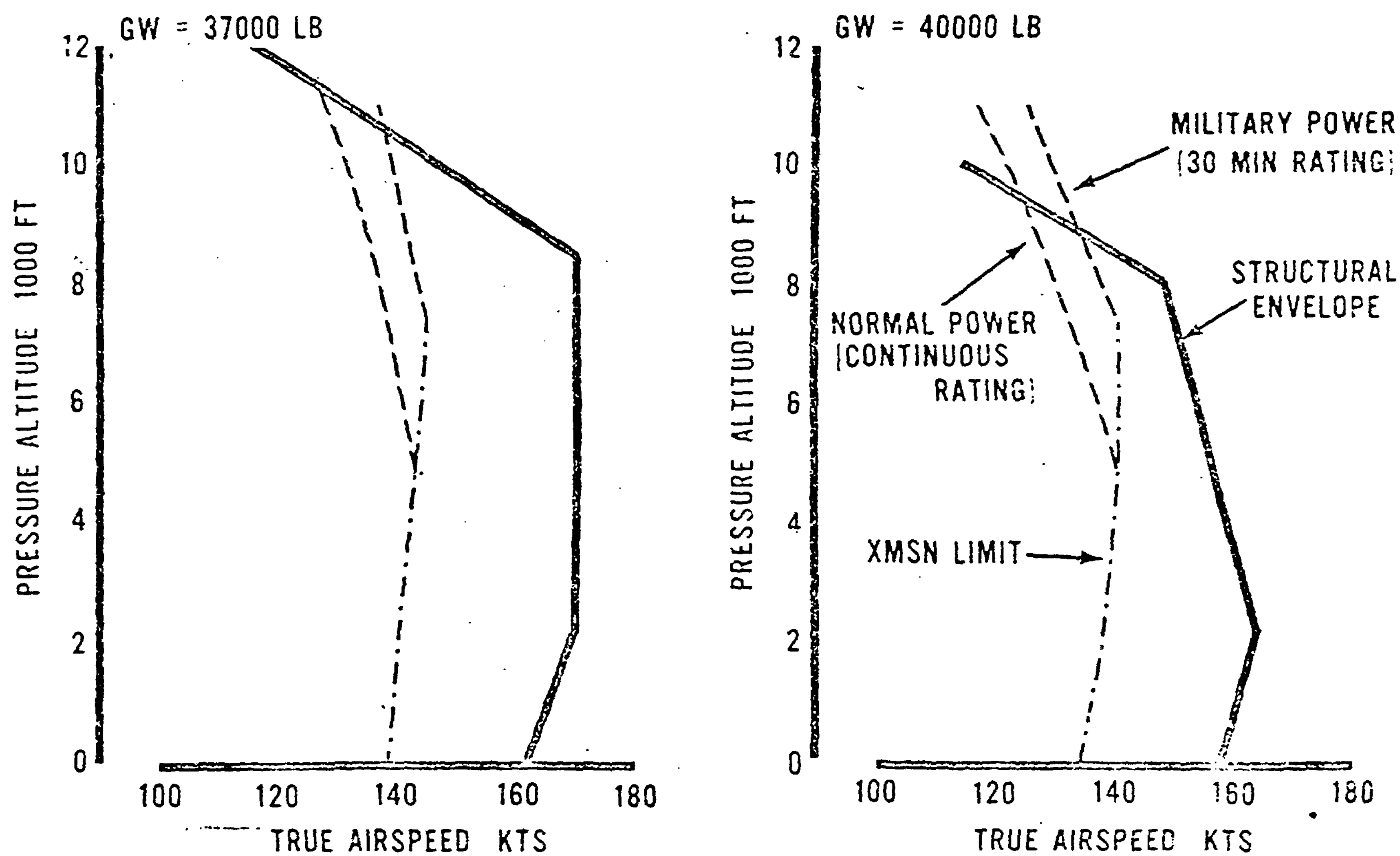
SLIDE 6.

WATER ATOMIZER



SLIDE 7.

CH-47C SPEED CAPABILITY WITH ICE SPRAY RIG CONSTANT 20°F TEMP



SLIDE 8.

HELICOPTER IN FLIGHT TEST FACILITY SCHEDULE

SPRAY RIG DELIVERY TO ASTA	30 DEC 1972
SPRAY RIG CARRIER CH-47C TO ASTA	2 FEB 1973
INSTRUMENTATION & ENGINE CHANGE ON ACFT	5 MAR 1973
INSTALL & INSTRUMENTATION OF SPRAY RIG	19 MAR 1973
FLT ENVELOPE DEVELOPED & QUALIFICATION COMPLETE	20 APR 1973
MOVE TO FT GREELY ALASKA	1 MAY 1973
ICING BASE LINE DATA ON ALL FIRST LINE ARMY HELICOPTERS COMPLETE	1 NOV 1973

SLIDE 9.

SUMMARY

- WE NEED TO FIRM UP OUR IFR REQUIREMENTS TO A CONSISTANT LEVEL WITH OTHER AIRWORTHINESS QUALIFICATION REQUIREMENTS
- INSURE SUCH REQUIREMENTS ARE ADEQUATE BUT NOT GOLD PLATED.
- EXPAND TEST EFFORTS TO INCLUDE FLIGHT UNDER INSTRUMENT CONDITIONS INCLUDING ICING.

SLIDE 10.

SESSION I

USAASTA IFR TESTING

MODERATOR

COLONEL DEAN E. WRIGHT
USAASTA

PANELISTS

MR. RICHARD B. LEWIS, II, USAASTA

MAJOR JOHN R. SMITH, USAASTA

MAJOR WARREN E. GRIFFITH, USAASTA

MR. JOSEPH C. WATTS, USAASTA

MAJOR JOHN R. BURDEN, USAASTA

USAASTA PANEL PHOTOGRAPH 1.

USAASTA PANEL PHOTOGRAPH 2.

INTRODUCTION OF PANEL BY COLONEL WRIGHT

COLONEL DEAN E. WRIGHT
COMMANDER, US ARMY AVIATION SYSTEMS TEST ACTIVITY

General Maddox and guests. As the first technical session of the day, we are to present the results of the testing which we have done at the Army Aviation Systems Test Activity. The presentations are not intended as an endorsement or disparaging remarks on the equipment, but only our evaluation of the equipment which we have been directed to test.

So we will start with Mr. Richard Lewis, my Deputy Director of Flight Test, who will outline the test requirements for determining instrument flight capability. Dick is an honors graduate from Princeton University and holds a masters degree from Rensselaer Polytechnic Institute. He spent five years at Sikorsky Aircraft and two years at Lockheed prior to coming to the Activity in 1969.

A member of the AHS, AIAA, SFTE, and Royal Aeronautical Society, Mr. Lewis has authored papers on Remote Terminal Computing, Jet Flap Rotor Research, Helicopter Maneuverability, and Helicopter Performance Trends Mr. Lewis is a member of the National AHS Committee on Flying Qualities and the AIAA Committee on Flight Testing.

DETERMINING HELICOPTER IFR FLIGHT CAPABILITY

RICHARD B. LEWIS, II
DEPUTY DIRECTOR OF FLIGHT TEST
US ARMY AVIATION SYSTEMS TEST ACTIVITY

This paper serves as a preamble to those that follow (refs 1 to 4) which discuss four US Army Aviation Systems Test Activity (USAASTA) test programs to investigate Instrument Flight Rule (IFR) capability for the OH-58A, OH-6A, AH-1G and CH-54B helicopters. It will discuss helicopter stability and control requirements, qualitative evaluation of handling qualities, measurement of pilot workload, and determination of aircraft flight path accuracy.

A recurring theme in all those presentations is the importance of stability and control in the determination of IFR capability. Of course, there are many other factors – crew requirements, displays, cockpit environment, mission requirements, navigation and guidance, aircraft subsystem performance and reliability – but the requirements of acceptable stability and control dominate. For the purposes of this discussion stability is defined as the tendency to maintain an equilibrium once it is established. Control is the capability to effect changes in equilibrium, that is, to alter the flight path at the command of the pilot. The controls may also be used to supplement the stability of the system when commanded by either the pilot or an automatic controller. It is interesting to observe that the subtle interrelationships between stability and control played a crucial role in the pioneering development of fixed wing aircraft (ref 5).

Slide, please (slide 1)

Those familiar with the history of fixed wing aircraft will recall the Lilienthal glider and Wright biplane experiments conducted around the turn of this century. Figure 1 illustrates both aircraft and some notable contrasts are seen. Lilienthal designed his glider with stability in mind – large fixed tail surfaces are evident. However, control surfaces, elevator, aileron and rudder are noticeably absent and limited control was achieved by center of gravity (the pilot) motion. The Wright Brothers' aircraft differs considerably. Large control surfaces, an all moving canard in front and rudder in the rear, provided substantial control – but no stability. The aircraft was longitudinally unstable, had about neutral directional stability and negative dihedral and required considerable pilot control to achieve flight.

It is noted that both the above approaches to aircraft design achieved some limited success. Lilienthal made many glider flights but was killed when a gust overpowered the stability of the aircraft and inadequate control remained for recovery. The Wright Brothers' flights were of very short duration and by their own descriptions involved pilot overcontrolling most of the time. Flights frequently ended when, at the bottom of an oscillation, the aircraft contacted the ground. It was not until the intricate interrelationships between stability and control were understood that successful fixed wing aircraft were developed.

A similar but even more delicate balance between stability and control is inherent in helicopters. The rotor itself is unstable and fixed external surfaces must be provided to counteract this instability. The effectiveness of these control surfaces is degraded by the turbulent wake emanating from the rotor hub and usually bluff fuselage afterbodies as well as by strong destabilizing rotor-induced sidewash and downwash. Since weight and balance considerations frequently restrict tail size, the design goal of a statically stable helicopter is rarely achieved. Designers attempt to make the helicopter flyable through control, but the end result is that all Army helicopters exhibit instabilities – several examples of which appear in figure 2.

Next slide (slide 2)

The control problem is more acute for helicopters than fixed wing because there are more degrees of freedom, modes of control and inherent control cross couplings. A fixed wing airplane can translate in only the forward direction while the helicopter moves freely forward and aft, up and down, left and right – and any combination of these. The helicopter must be controlled during hover, transition and forward flight – all of which place varied demands on control. Experience has shown that adequate control in one flight regime may be insufficient in another. These factors as well as the complex mechanical requirements of helicopter control systems have produced a number of helicopter control problems – several examples of which are shown in figure 3.

Next slide (slide 3)

The stability and control requirements applied to Army helicopters are contained in Military Specification MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities: General Requirements For* (ref 6). These requirements are listed by category in figure 4. The following paragraphs briefly describe the requirements of MIL-H-8501A. The importance of these handling qualities requirements as they relate to IFR flying tasks is discussed in references 1 to 4.

Next slide (slide 4)

Mechanical control system characteristics requirements include specific breakout forces, including friction, control force gradients and linearity, limit control forces and control force cross coupling. Objectionable transient control forces are prohibited. The ability to trim steady-state control forces to zero and positive self centering characteristics are required.

Longitudinal and lateral trim changes with speed and power are limited. Control margins about those axes are required to counteract disturbances such as gusts or turbulence in any flight regime. Maximum transient control motions during a steady hover are specified for all controls.

Control input fidelity requires the development of aircraft motion in the commanded direction without objectionable or excessive delays. The specification also prohibits adverse response of the helicopter about an uncommanded axis.

Collective fixed static longitudinal control position and control force stability are required. These are evidenced by the requirement for forward longitudinal control displacement and push force with increasing forward airspeed and aft displacement and pull force with decreasing airspeed. The implicit requirement, however, is that the aircraft possess both angle of attack and speed stability which are the tendencies to resist changes to angle of attack and airspeed respectively.

Static lateral-directional stability is required which includes both directional stability and dihedral effect. Important also, although not specifically required, are positive sideforce characteristics which reinforce pilot sideslip cues.

Maneuvering stability requirements are stipulated in terms of nondivergent normal acceleration and pitch rate following a control input. The aircraft response must be consistently in the command direction. Additionally, limits are specified as to the maximum allowable controls fixed normal acceleration induced by a simulated gust.

Dynamic stability, the freedom from self-sustained natural oscillations, is stipulated in terms of damping required for various frequency ranges. For visual flight rule (VFR) operations only longitudinal dynamic stability is required by the specification. However, for IFR flight both longitudinal and lateral-directional dynamic stability are specified. Objectionable adverse yaw is prohibited for both VFR and IFR flight.

Control power is defined as the angular rate produced within a given time interval following a step control input. Angular rate damping is the tendency of the aircraft to resist aircraft angular rates. Minimum values of control power and angular rate damping are established by MIL-H-8501A. For IFR flight these requirements are more severe than for VFR flight. Limits to lateral and directional control power are specified to preclude overcontrolling.

The specification requires that certain maneuvers be possible without undue control requirements. These include constant height accelerations and decelerations between hover and maximum forward speed; stabilized sideward flight to 35 knots in each direction and rearward flight to 30 knots; taxiing in winds; hovering turns; coordinated turns during autorotation; cyclic only forward flight turns; starting, takeoffs, landings and stopping in winds; and autorotational entries with controls fixed for a specified delay time.

For helicopters employing boosted control systems and/or automatic stabilization equipment more stringent requirements for control feel and aircraft stability are required. In addition, failure modes must permit continued safe flight with stipulated control margins.

Throughout the flight envelope the helicopter is required to be free from objectionable shake, vibration or roughness. Specific vibratory amplitude limitations are required for pilot, crew, passenger and litter stations.

In addition to the increased control power, angular rate damping and dynamic stability required for IFR flight, MIL-H-8501A stipulates that flight using instruments should not demand undue pilot effort. In order to determine compliance with this requirement both qualitative and quantitative means of determining pilot effort must be defined.

Before addressing the subject of pilot effort it should be mentioned that MIL-H-8501A is over a decade old and is currently in the process of revision jointly by the Army and Navy. Experience has proven that a viable handling qualities specification should consider variation in mission requirements, can better quantify specific stability and control requirements and will benefit from further integration of VFR and IFR requirements. The new specification MIL-H-8501B will be evolutionary, however, and will draw heavily upon the present specification. Meanwhile new Army procurements such as UTTAS include definitive handling qualities specifications for that vehicle. In the meantime USAASTA continues to apply the requirements of MIL-H-8501A to IFR flight evaluation, along with a host of other criteria. It is emphasized that instances exist where an aircraft characteristic cannot meet the specification requirement but is satisfactory for IFR flight and vice versa.

Qualitative evaluation of helicopter handling qualities can be a very difficult undertaking. Noise and vibration distract the evaluator. In addition, the coupled response so prevalent with rotary wing aircraft tends to obscure single well-defined rating tasks. Nonetheless, a remarkable degree of uniformity in pilot rating can be obtained when consistent ground rules are applied.

Next slide (slide 5)

The Handling Qualities Rating Scale (HQRS) applied by USAASTA is shown in Figure 5. It is based upon the Cooper-Harper Handling Qualities Rating Scale (ref 7) with modified definitions of deficiency and shortcoming consistent with standard Army nomenclature (ref 8). It is noted that ratings are assigned based on a logical flow diagram which involves the adequacy of the aircraft response for a selected task or operation and identification of the aircraft characteristics and level of pilot effort during that task.

An essential ingredient in the HQRS is specification of the task. Clearly intrinsic stability and control parameters, for example short period damping ratio or directional control free play, cannot be assigned an HQRS score. However, when placed in the context of a piloting task, such as the ability to maintain pitch attitude in gusting air or maintaining heading during an instrument approach – which depend on the above factors (and many others) – a pilot rating can be applied.

Because the tasks associated with HQRS ratings almost always implicate more than one stability and control characteristic, it is very difficult to associate pilot ratings with individual or combinations of quantitative aircraft parameters. There are a number of published studies attempting to do this, but a majority employ either airplanes or simplified fixed base V/STOL simulator models. The relative complexity of helicopters and, specifically IFR piloting tasks, lead the investigator to seek other means of quantifying pilot performance and workload.

Those familiar with the manned space program will recall the extensive physiological instrumentation of the astronauts. Parameters such as pulse rate, blood pressure, respiration rate and content, electrocardiogram waveforms, perspiration rate and salinity, etc. have been useful in determining pilot well-being and workload. To so measure pilot effort is considerably beyond the scope of any known V/STOL flight tests and is well beyond USAASTA mission responsibilities. Further, it is noted that the astronaut is only intermittently required to actively control his vehicle, whereas the helicopter pilot's task is continuous. This leads to the hypothesis that the pilot/machine interface may yield meaningful pilot workload information.

Next slide (slide 6)

Figure 6 illustrates several approaches to determining pilot workload from control activity. Typical traces of control position versus time reveal considerable control activity. Since control systems typically include breakout forces and control force versus position displacement gradients, the control activity requires an expenditure of pilot work which over a period of time is equivalent to power.

The root mean square (RMS) control position is one form of weighted average over a given time interval. The difference between the RMS and trim control position is therefore a pilot workload indicator. However, typical RMS minus trim values are small, thus making such comparisons susceptible to calculation inaccuracies.

A line integral of control displacement versus time when multiplied by the average control gradient corresponds approximately to pilot power required. This appears to be an ideal pilot workload parameter to monitor but insufficient data presently exist to validate this assumption. The USAASTA is presently developing instrumentation to measure this parameter directly.

Another indicator of pilot activity is obtained by analyzing control reversals. The frequency and amplitude of these control reversals appears to be related to the level of pilot effort in testing conducted to date.

Several approaches to pilot activity determination have been explored. The simplest is to count control reversals per unit time. This approach does not yield absolute data since it is clearly dependent upon the flight conditions at the time of the test. It can, however, be compared to other data obtained under the same flight conditions. This has been done for the OH-58 by flying identical mission segments with the same aircraft and pilot and varying VFR/IFR, SAS ON/OFF, flight director ON/OFF in sucessive test points. Data are averaged for several runs to ensure consistency.

Control activity can also be analyzed to produce nonrelative measures of pilot workload. By categorizing control reversals in segments of differing amplitude it is possible to identify the percentage of control reversals in excess of the mean. This "excess pilot workload" may be a factor in the formation of pilot opinion.

It should be apparent that the analysis of control activity can involve considerable data manipulation. With conventional oscillographic data acquisition systems, the extent of such data processing is severely limited. Current and future USAASTA IFR flight test programs will employ an advanced instrumentation and data acquisition system (AIDAS). The AIDAS consists of airborne data encoding and magnetic tape recording equipment and ground based decoding equipment under computer control. This equipment permits extensive "hands off" data analysis and permits several test and analysis techniques not possible with conventional flight test data systems.

Computer programming is complete and use of extensive pilot workload analysis software is under way at USAASTA. Program capability includes determination of mean, variance, maximum, minimum and standard deviation of control activity for all pilot controls. The data can be further analyzed to determine frequency and magnitude of upper and lower control half-cycles, their means and statistical attributes. Control residency in a given control position band – a form of control density analysis – is also determined. Control position integrals, their distribution by peak amplitude, and a number of other data calculations are performed.

It is expected that this extensive control analysis capability will result in a new insight into pilot workload measurement. It is probable that the information obtained will point toward even different analytical approaches. Perhaps discussions during the Helicopter Instrument Flight Conference (ref 9) will identify still other control analysis methodology.

The measurement of aircraft performance is far simpler than pilot workload. Principal flight path parameters such as airspeed, altitude, rate of climb and heading can be recorded using oscillograph or AIDAS. If a normal distribution is assumed, then the statistical determination of mean, standard deviation, variance, maximum and minimum will represent the flight path accuracy.

Next slide (slide 7)

For the purposes of the referenced tests (refs 1 to 4) two approaches to flight path accuracy are taken. To obtain a representative overview of mission performance a simulated IFR mission is flown. Figure 7 illustrates the mission profile which includes takeoff, climb, enroute navigation, beacon intercept and approach to a landing. Throughout the mission the aircraft is tracked by NASA ground based space positioning radar. Analysis of the actual versus desired flight path provides an overall indication of aircraft mission capability. Missions are flown sucessively VFR and IFR and if applicable with and without additional displays, stability augmentation, etc. in an attempt to minimize effects of uncontrolled variables such as atmospheric turbulence. When appropriate, different pilots fly the mission.

In addition to the above mission performance analysis, the mission is divided into distinct segments (level flight, climb, descent, turns, etc.) which are subjected to more elaborate scrutiny. Each mission segment is flown several times under comparable atmospheric conditions while varying VFR/IFR, stability augmentation and pilot displays. Tests are then repeated under different atmospheric conditions. Flight path accuracy is determined for the onboard parameters (airspeed, altitude, rate of climb and heading) and averages are obtained for the various atmospheric conditions tested. By averaging it is felt the resulting flight path accuracy data permit acceptable comparisons with similarly obtained data.

In conclusion, testing to determine helicopter IFR capability is a complex mixture of qualitative and quantitative analysis of aircraft stability and control, pilot workload and flight path accuracy. The following papers (refs 1 to 4) will present specific examples of how these factors are related to the OH-58A, OH-6A, AH-1G and CH-54B helicopters. It will be shown that improved instruments and displays significantly influence the pilot workload/aircraft performance mix. However, residual to all of the discussions is the fact that acceptable instrument flight capability depends on adequate helicopter stability and control.

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7. Technical Note, NASA TN-D-5153, *The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities*, Cooper, George E. and Harper, Robert P., April 1969.

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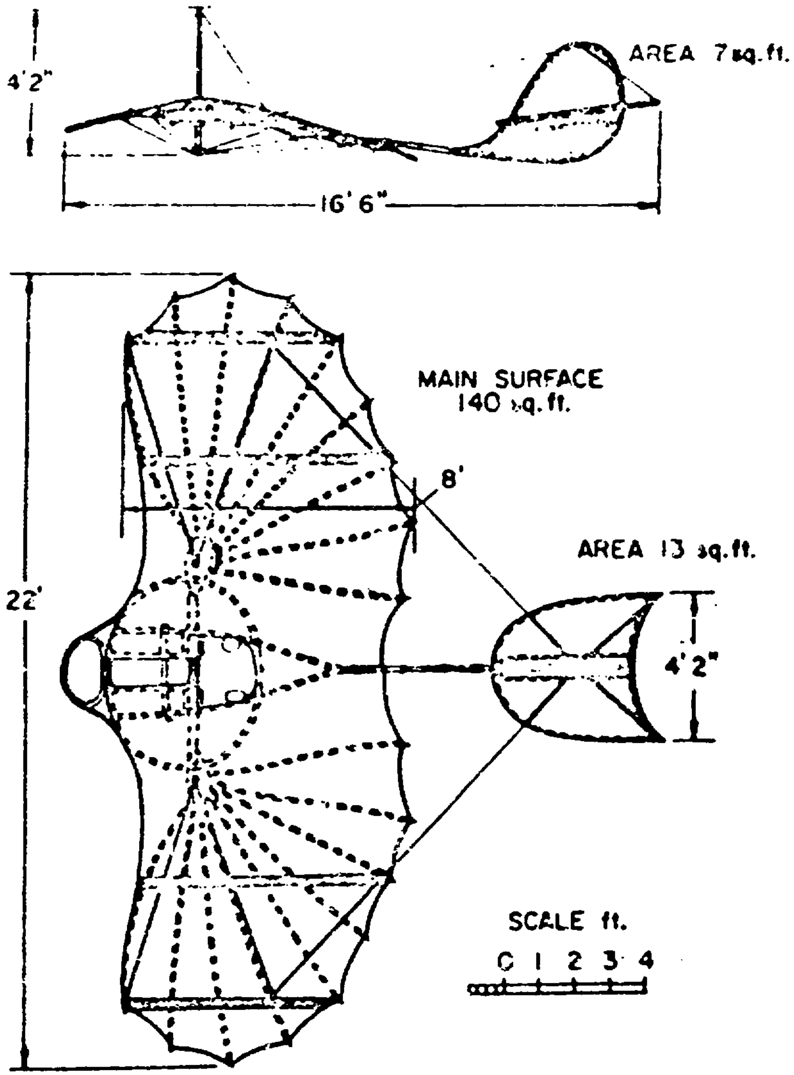
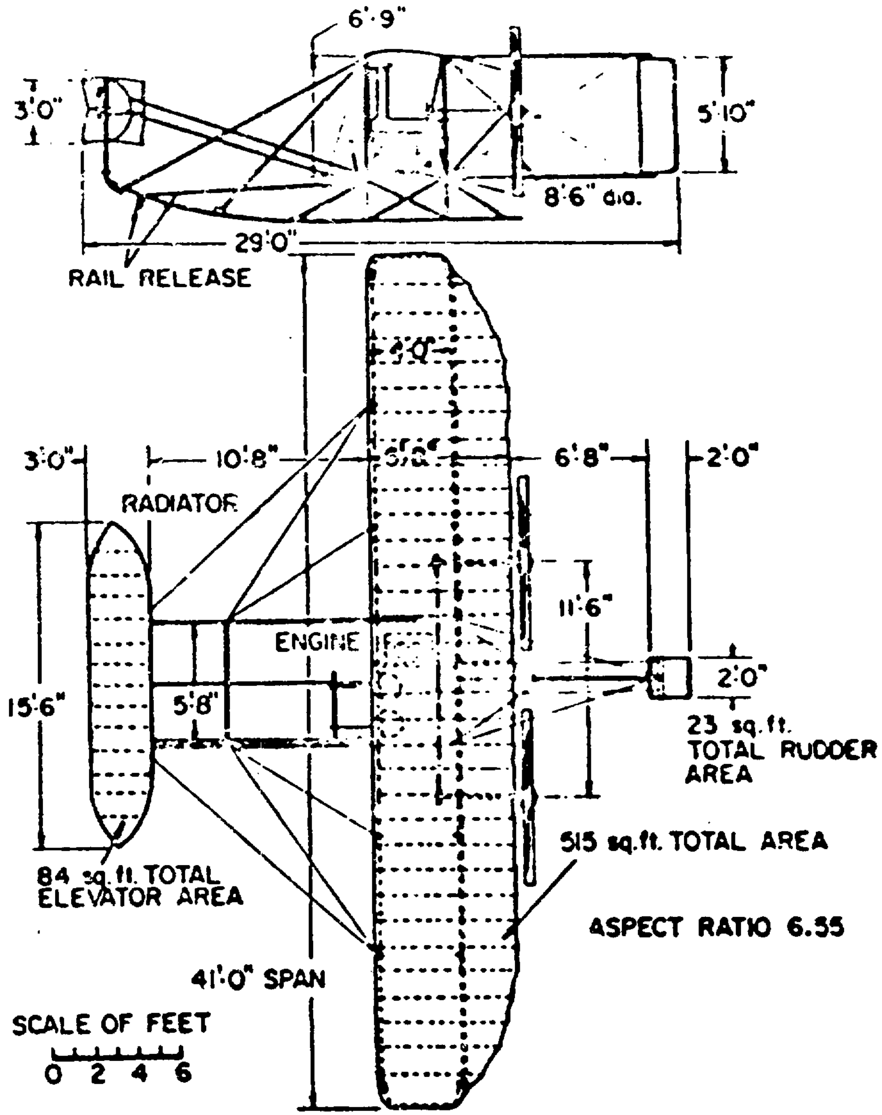


Lilienthal glider.



Wright biplane.

SLIDE 1.

FIGURE 2

SELECTED HELICOPTER STABILITY PROBLEMS

OH-58A	DUTCH ROLL TENDENCY/LACK OF SPIRAL STABILITY.
OH-6A	NEUTRAL STATIC LONGITUDINAL STABILITY.
UH-1M	LACK OF DIEHDRAL EFFECT AT LOW GROSS WEIGHT.
UH-1H	POOR DIRECTIONAL DAMPING.
AH-1G	LACK OF PITCH CHANGE WITH AIRSPEED.
CH-47C	DIFFICULTY TO OBTAIN AND MAINTAIN DESIRED AIRSPEED.
CH-54B	DEGRADED STATIC STABILITY AT AFT CG.

SLIDE 2.

FIGURE 3

SELECTED HELICOPTER CONTROL PROBLEMS

OH-58A	UNSATISFACTORY PEDAL FORCE CHARACTERISTICS.
OH-6A	INADEQUATE CYCLIC CONTROL CENTERING.
UH-1M/H	FORCE TRIM DISENGAGEMENT WHEN RETRIMMING.
AH-1G	MARGINAL COPILOT CONTROL SYSTEM.
CH-47C	POOR TRIMMABILITY CHARACTERISTICS.
CH-54B	INADEQUATE DIRECTIONAL CONTROL MARGINS AT HEAVY WEIGHT & HIGH ALTITUDE

SLIDE 3.

FIGURE 4

MIL-H-8501A HANDLING QUALITIES REQUIREMENTS

MECHANICAL CONTROL SYSTEM CHARACTERISTICS

LIMITED TRIM SHIFTS/SUFFICIENT CONTROL MARGINS

CONTROL INPUT FIDELITY

STATIC LONGITUDINAL STABILITY

STATIC LATERAL/DIRECTIONAL STABILITY

MANEUVERING STABILITY

DYNAMIC STABILITY & AIRCRAFT MOTION DAMPING

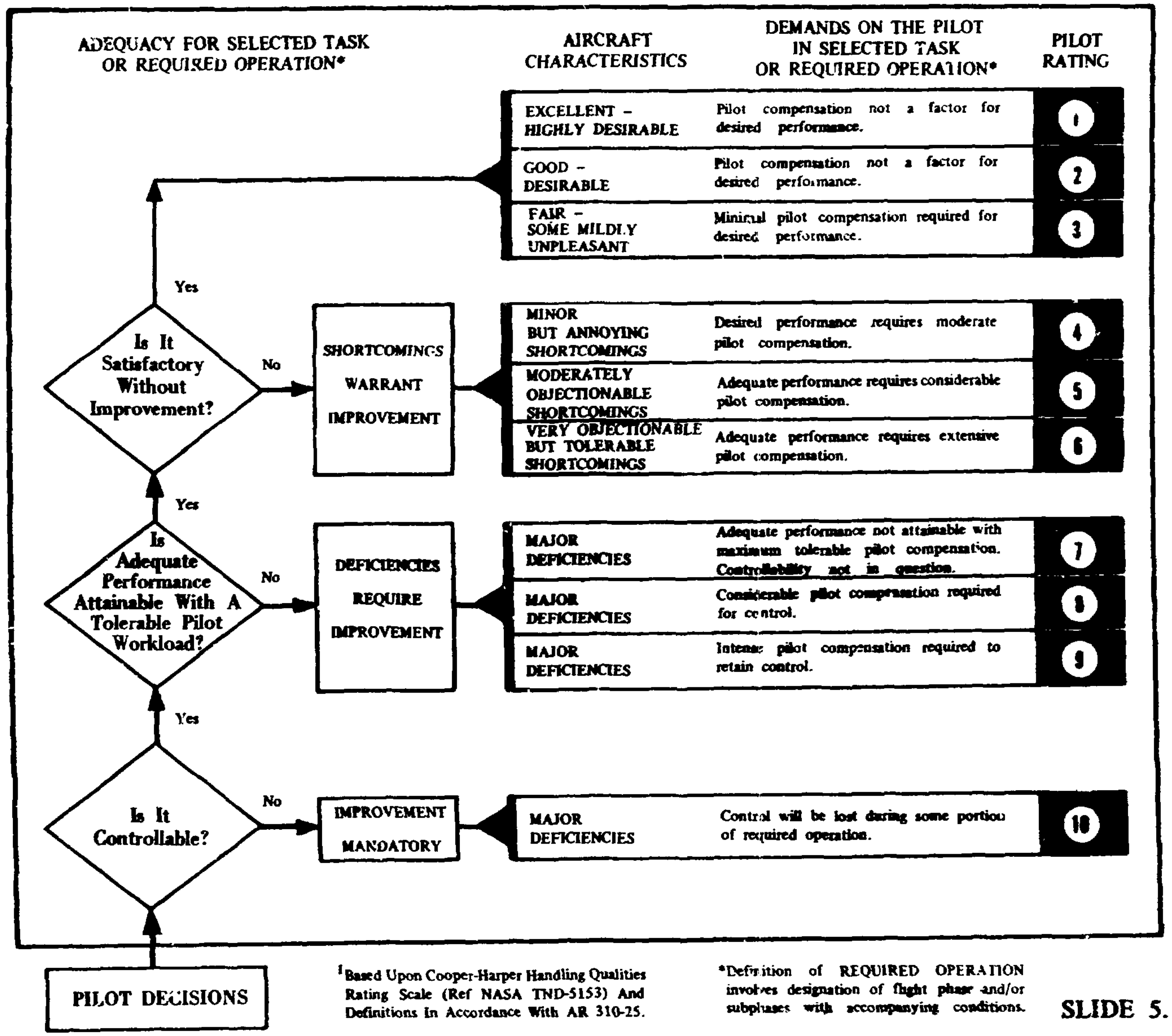
PERFORMANCE OF SPECIFIC MANEUVERS

BOOSTED CONTROL & ASE PERFORMANCE

FREEDOM FROM VIBRATION & ROUGHNESS

ADDITIONAL IFR REQUIREMENTS

SLIDE 4.

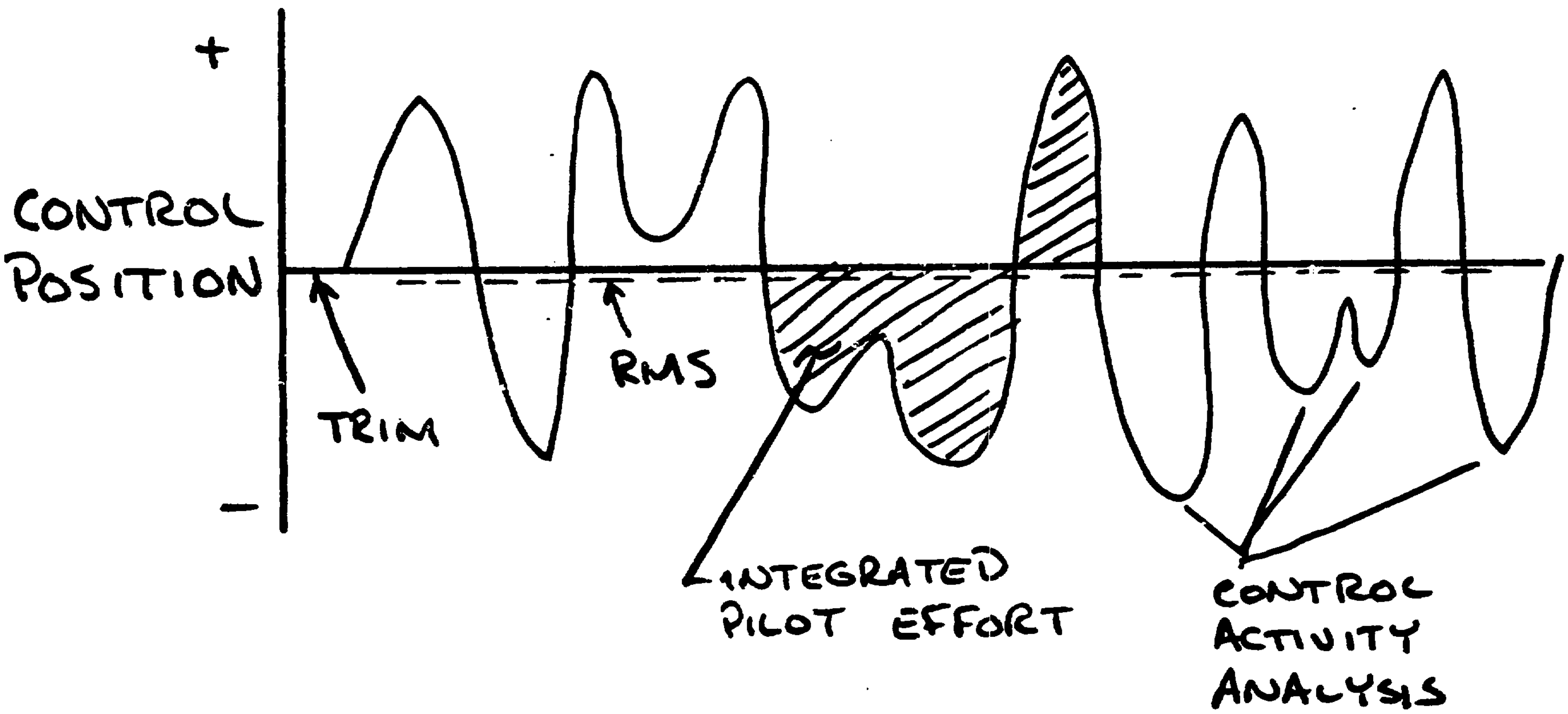


[1] Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) And Definitions In Accordance With AR 310-25.

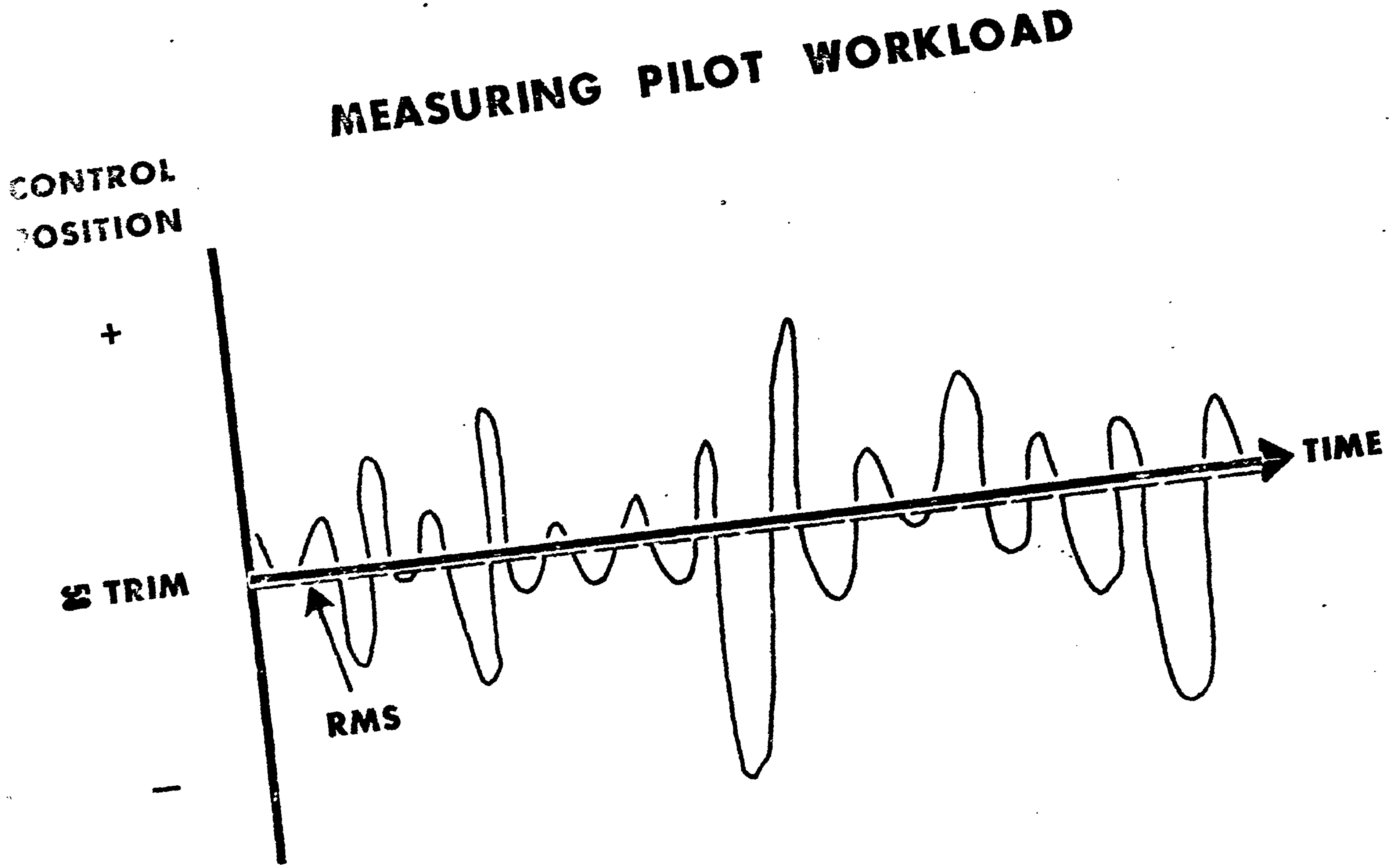
*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

SLIDE 5.

MEASURING PILOT WORKLOAD

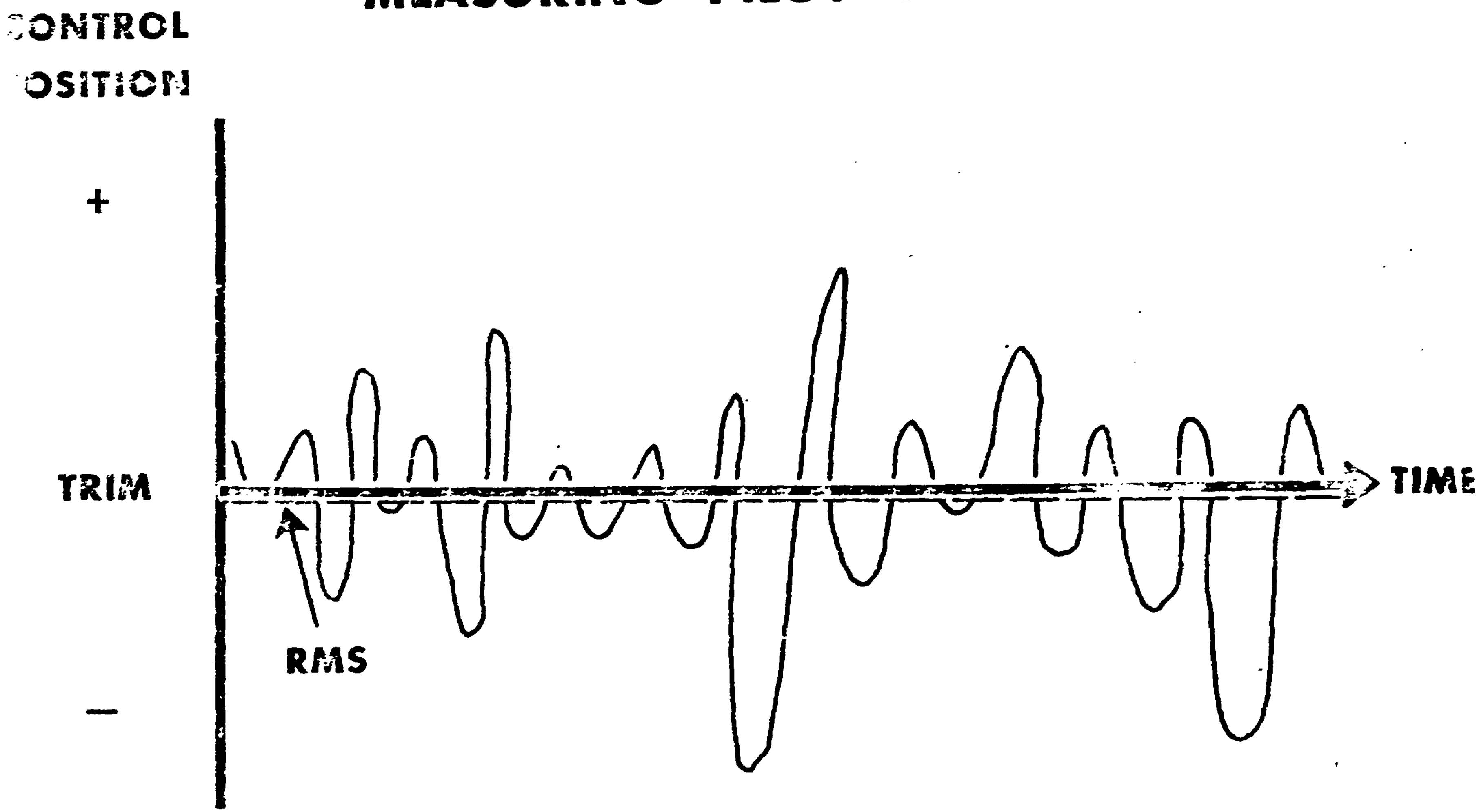


SLIDE 6.



SLIDE 6A.

MEASURING PILOT WORKLOAD

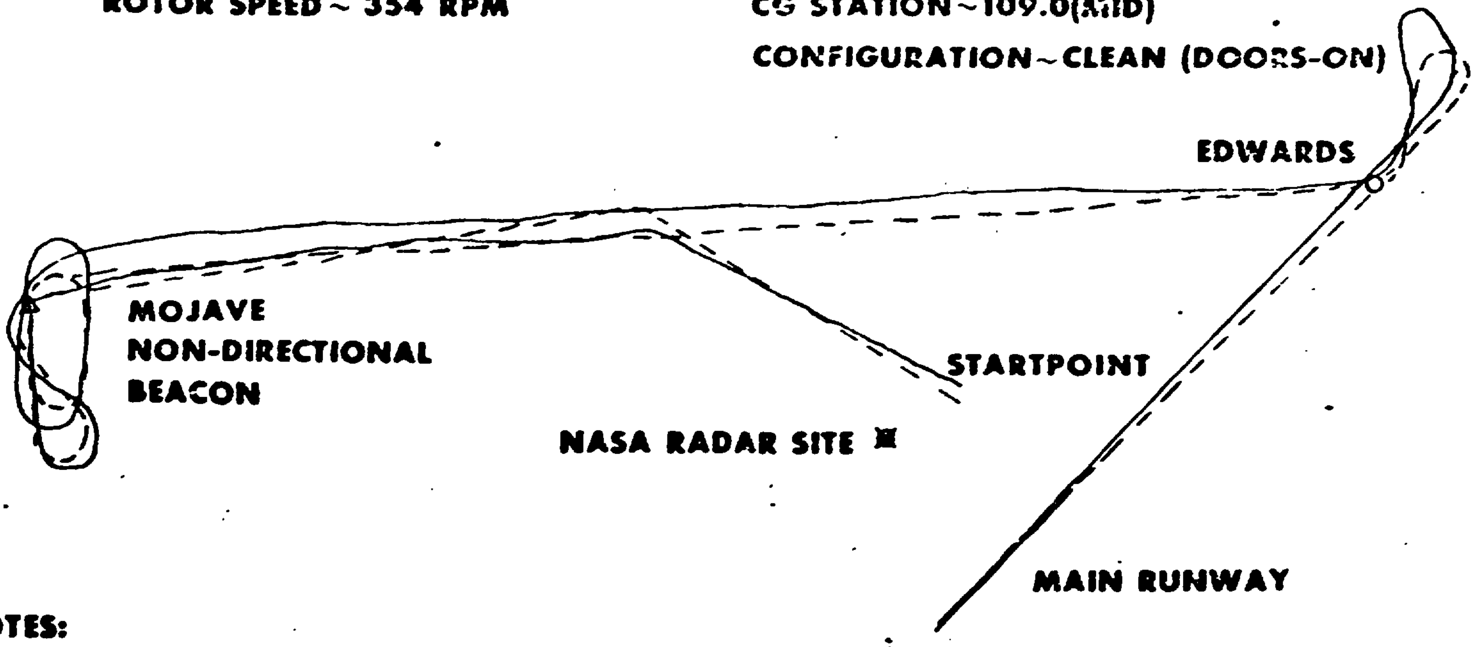


SLIDE 6B

IFR MISSION PROFILE WITH FLIGHT DIRECTOR

CALIBRATED AIRSPEED ~ 88 KTS
ROTOR SPEED ~ 354 RPM

GROSS WEIGHT ~ 2800 LBS (AVG)
CG STATION ~ 109.0(MID)
CONFIGURATION ~ CLEAN (DOORS-ON)



NOTES:

- BLACK LINE REPRESENTS THE THEORETICAL NO WIND MISSION PROFILE ENVELOPE
- RED LINE REPRESENTS THE ACTUAL MISSION PROFILE ENVELOPE
- WEATHER CONDITIONS, SURFACE WINDS CALM WINDS AT 7000 FEET 5KTS AT 115° MAGNETIC
- SCALE 1 INCH 2 NAUTICAL MILES

SLIDE 7.

COL WRIGHT: Our next speaker will discuss the test of the OH-58, Major John Smith. John graduated from North Georgia College in 1959, completed flight training in 1961, graduated from test pilot school in 1969, and joined the Activity in June of 1971. Since that time he has participated in UTTAS Maneuvering Test, OH-58A IFR Testing, OH-58A 3-Axis SCAS Evaluation, and the Attack Helicopter Requirements Evaluation.

OH-58A TESTING

MAJOR JOHN R. SMITH
EXPERIMENTAL TEST PILOT
US ARMY AVIATION SYSTEMS TEST ACTIVITY

The OH-58 is a 4-place, single rotor helicopter of the teetering rotor type with a maximum speed of 120 knots. It has hydraulic boosted cyclic and collective controls but unboosted directional controls. It is powered by an Allison engine that provides 317 horsepower (standard day, sea level).

First slide (slide 1)

The testing of the OH-58 was set up to determine if the aircraft met the IFR requirements of MIL-H-8501A and was safe to fly under instrument conditions.

The testing sequence was initially set up in three phases which were:

1. Flying qualities and specification compliance testing.

2. Operational testing to determine safety in the IFR environment, and

3. Pilot workload testing with and without a flight director.

At the end of phase 3, it was determined that the standard OH-58 was unsatisfactory for IFR flight – the specific reasons for which we will discuss in a moment. A decision was made to conduct a fourth phase which included adding a 3-axis stability and control augmentation system (SCAS) and to retest the aircraft.

Next slide (slide 2)

The SCAS used was the model 570B manufactured by Bell Helicopter Corporation (BHC) and which provided rate damping in the pitch, roll and yaw axes. The major components are shown here on this slide. Directional pedal hydraulic boost was included in this system.

The IFR evaluation of the OH-58 included both engineering and operational testing. The major test areas are listed on the right side of this slide.

Next slide (slide 3)

The tests in which the aircraft was satisfactory are shown by the black X's. The areas where discrepancies were noted are indicated by the red X's, and only these tests where problems were noted will be discussed. We will first cover the test results of the standard aircraft followed by the results after the SCAS was added.

Next slide (slide 4)

The first test we will discuss is control system characteristics. This is an area that has been very much emphasized in fixed wing aircraft for many years, but only recently in helicopters. The factors that we considered during this test are listed on the slide, all of which are important and significantly influence the pilot workload to perform an IFR task, whether it be level cruise or an instrument approach.

We found that all factors, or characteristics, listed were satisfactory for the OH-58 with the exception of control centering. Centering is nothing more than the control returning to the same trim position each time it is displaced and the pressure relaxes. This characteristic is important during IFR flight because of the frequent requirements for additional pilot tasks, such as changing radio frequencies, etc. Centering is provided in the OH-58 by a magnetic brake and force gradient spring on the cyclic. The pedals rely on aerodynamic forces and friction to maintain a near center position. The most significant problem was in the longitudinal control, in which the force gradient was masked by breakout and friction as shown on this slide.

Next slide (slide 5)

What this means to the instrument pilot is a trim speed band of about 15 knots in which the cyclic can be placed, before the force gradient spring overrides the breakout and friction.

An optimum system displaying good design practice is also shown, and you can see that any time the control is displaced and released, it will return to the same trim position. Similar centering characteristics, but not as critical, were found in the lateral and directional controls of the standard aircraft.

Project yourself some months later to the completion of the SCAS evaluation. How did it affect the centering problems we have identified? It did nothing for the longitudinal axis, but it did reduce the adverse effect of the poor centering in the lateral control to the point where it was satisfactory. This was accomplished by improving aircraft damping in the lateral and directional axes. We will discuss this more in a few minutes. As we stated earlier, the SCAS installation included adding hydraulic boost to the directional controls. This modification reduced pedal forces to a point where there was essentially no force gradient.

Slide (slide 6)

As shown on this slide, if you follow the trace, you can see that pedal forces become less as the right pedal goes in. Also note that there is essentially no centering. Compare this to a good design practice curve again. Both the poor centering and inadequate force gradient characteristics are objectionable during instrument flight because of the inadvertent sideslips which result. To correct this discrepancy BHC modified the directional controls by adding a force gradient spring and magnetic brake unit. The results from our tests of the modified system are shown on this slide.

Next slide (slide 7)

With this modification the directional control system characteristics are now satisfactory.

Next slide (slide 8)

CONTROLLABILITY The next test was controllability in which we evaluated control power and damping. A helicopter must have a good blend of control power and damping to have agility. We will first consider damping. A heavily damped helicopter normally makes a better instrument aircraft, but you still need the control power to go with it, especially when the aircraft is to be a Scout as in the OH-58.

Next slide (slide 9)

The specification provides us with hover control power and damping requirements which are good indicators when evaluating an aircraft for a mission.

Next slide (slide 10)

This chart shows the requirements for a 1-inch displacement at the end of 1 second as well as the actual test results of the OH-58. As you can see, the aircraft has plenty of control power in all the axes but damping in lateral and directional axes is weak, especially directional. You might ask how this affects the instrument pilot. First of all it makes the hover task and the instrument takeoff very difficult. Once in flight, the effects of turbulence require constant attention to maintain a heading. Again let's jump ahead and see what effect the SCAS had on the aircraft controllability. Control power was not significantly effected by the SCAS; however, damping was, as shown on this slide.

Next slide (slide 11)

Also shown on this slide is a comparison of aircraft damping with and without SCAS compared to the specification. Notice the improved damping in the directional axis compared to the standard aircraft The additional effects of this increased damping will be discussed throughout the other tests.

Next slide (slide 12)

DYNAMIC LATERAL-DIRECTIONAL STABILITY We will next discuss two of the dynamic axes, lateral and directional combined. The cross coupling between the two make it impossible to separate them. In this test we are looking for damping of external disturbances.

Next slide (slide 13)

This is normally seen by the instrument pilot through yaw or roll oscillation, or if the two oscillations couple, you have an aircraft response called the "Dutch roll" which can become very distracting to the pilot in instrument conditions. The OH-58 possessed these undesirable characteristics under certain loading conditions.

Next slide (slide 14)

Engraved also into the lateral-directional dynamics of the aircraft is an additional characteristic called the spiral stability or graveyard spiral. This is the way an aircraft reacts in the roll axis following a gust. It can be convergent, divergent or neutral. The basic OH-58 is neutral. This means that a gust will cause the aircraft to roll off the trim heading and continue the turn. The lateral-directional dynamics of the OH-58 is one of the most objectionable characteristics. With these problem areas, we would hope the SCAS would help and it did indeed. Lateral and directional oscillations were individually well damped by the SCAS and in turn the lightly damped Dutch roll characteristics were essentially eliminated as shown here.

Next slide (slide 15)

Also, the spiral stability was improved. Now the aircraft will right itself after the effects of a gust from neutral to stable. Of all the benefits of the SCAS – this was the most significant area.

Next slides (16 and 17)

COCKPIT EVALUATION I would now like to briefly discuss the OH-58 cockpit as shown on this slide. The standard aircraft cockpit has several areas that need improvement for instrument flight. As you can see, the aircraft does not have a vertical speed indicator, which is essential. A modification kit was available in the supply system for the OH-58 which was added for the test. This instrument was marginally satisfactory because the scale of 0 to 6000 feet per minute did not allow the pilot to detect small rates of climb or descent.

Next slide (slide 18)

The attitude indicator in the standard aircraft did not provide sufficient information for the pilot to detect small roll and pitch changes. This was primarily due to the small size, lack of contrast in the colors used, as shown here, and the poor sensitivity.

Other problem areas were the lack of navigation radios to adequately perform an instrument flight, especially in CONUS. For example, with only the single ADF receiver it would not be possible to fly into Edwards IFR since there is no facility here. The number and type of additional navigation radios depend on the theater of operation in which the aircraft is to be used.

The preceding tests would normally complete a handling qualities evaluation. However, we attempted to put some quantitative values, or numbers, on the effect of all these stability and control characteristics combined in performing IFR flight, that is, "pilot workload."

Next slide (slide 19)

Our workload and flight path accuracy test procedures were already introduced. They are nothing more than measuring and recording on an oscillograph the total control reversals for various conditions. Flight path accuracy is measured two ways, first by space positioning radar which records a simulated IFR flight as shown on this slide and in segmented tests in conjunction with the workload tests. For pilot workload we used the basic aircraft VFR as our base line and compared everything to that. When I say VFR for this test, it means the pilot attempts to hold heading, airspeed and altitude as constant as possible using all references he has in the cockpit plus the horizon and outside terrain features. In order to minimize the effect of turbulence on our comparisons, the tests are conducted for 1-minute periods over the same terrain. For example, 1 minute of level flight data will be taken VFR followed immediately by 1 minute of IFR data over the same terrain. On a given test day, we will make several of these back-to-back comparisons and average the results. Turbulence level is also recorded on the oscillograph to better qualify the test day. Workload data can then be separated later or averaged again with other test days to show an overall comparison.

Next slide (slide 20)

This chart shows the data that we generated early in the evaluation. As you can see, it is much more difficult to fly this aircraft under the hood compared to VFR.

Following our initial evaluation on the OH-58, a Sperry Rand 2 cue flight director was added (2 cue means pitch and roll commands). We will come back to the flight director in a few moments and discuss how this particular unit works and some of the problems encountered with it. Adding the flight director eliminated some of the problem areas with the basic aircraft. For example, the director included additional navigation radios, an improved instrument display and the advantages of having the command bars. All these items combined reduced pilot workload in level flight as shown here; even with the benefits of the flight director, the pilot requirements were still too high for extended periods. It must be noted that these workload tests were conducted with full pilot attention to flying the aircraft.

Next slide (slide 21)

If he was diverted from the instrument panel momentarily to accomplish an additional pilot task, the aircraft deviated away from the desired trim conditions. Let's look at how the SCAS affected pilot workload.

Next slide (slide 22)

This chart shows the percent decrease in workload from the base-line condition (VFR, NO SCAS). As you can see, it was significant both VFR and IFR. Also shown is the flight accuracy data. Note the reduced error in heading with the SCAS on. This amplifies what we have already said, that the SCAS provided improvements in the lateral and directional axes. With the SCAS engaged, the flight director did not reduce workload or improve flight path accuracy. There are several reasons for this which will be discussed in a few moments.

Next slide (slide 23)

To sum up the OH-58 test, our evaluation revealed corrections are required in the following major areas to safely fly in instrument conditions: (1) stability augmentation is required in at least the roll and directional axes, (2) correction of the longitudinal control centering, (3) improved vertical speed and attitude indicators and (4) additional navigation radios depending upon the theater of operations.

Next slide (slide 24)

I must remind you that this evaluation is only a portion of a qualification process and other areas must also be considered such as icing, redundancy of equipment, etc.

At this point we are going to leave the OH-58 and discuss flight directors. One point should be made for those that are not familiar with the equipment and that is the term flight director is the description of a system that provides a display to the pilot and is in no way connected to the flight controls of the aircraft. The flight director is the first real attempt in the past decade to reduce the helicopter pilot's cross-check requirements. This is primarily done by combining all the essential flight data into one instrument. As you were told earlier, a Sperry Rand 2 cue flight director was installed in the OH-58 as shown on this slide.

Next slide (slide 25)

Remember, a 2 cue system is one with pitch and roll command bars. A 3 cue unit, which we will discuss in a moment, has pitch, roll, and collective commands. Specifically, the 2 cue test system was composed of the following components: flight director indicator, radio deviation indicator, radar altimeter, improved vertical speed indicator, VOR/ILS receiver and mode select panel.

Next slide (slide 26)

For illustration purposes we have isolated the key flight instruments of the system through the next series of slides. This slide depicts a condition in level cruise, heading hold and altitude hold. The flight director indicator has yellow command bars that present pitch and roll commands. Behind the bars is located a miniature airplane and a red dot. Behind all this is the artificial horizon. The radio deviation indicator is used for heading hold and for navigation course selection. The radar altimeter shows accurate height-above-the-ground data.

Next slide (slide 27)

This slide depicts a situation where the pilot's attention has been diverted. Note the vertical speed and attitude indicator. When he looks back at the panel he really only must check one instrument initially (the flight direction indicator). As you can see, the command bars are displaced. The pilot must mentally fly his miniature airplane to the yellow bar or in this case, it is telling him to roll left and pitch up.

Next slide (slide 28)

The condition shown in this slide is level cruise tracking to a VOR station. We will now discuss the functions of the radio deviation indicator. Navigation tracking is done with the course knob, course pointer and the roll command bars. This instrument can be used to navigate the same way that a CDI would be used in a standard aircraft; however, it is unique in that the command bar is coupled so the pilot need only look at one instrument. The radio deviation indicator is used for VOR, ILS and ADF tracking. The other major function of this instrument is heading hold. This is obtained by using the heading knob which is geared to the heading bug. These functions are coupled into the roll command bar and are used the same way as in navigation tracking.

Next slide (slide 29)

Let us now look at an ILS approach. The system includes an automatic capture feature for the glide slope when the aircraft reaches the proper position. This would normally be approached using altitude hold which is maintained by varying pitch attitude and airspeed. One reason the flight path accuracy was reduced, which was mentioned earlier, the pitch bar provides the commands to stay on glide path and roll bar provides command for the localizer course. Note the raw data glide slope information is provided on both instruments. This slide depicts the panel at the instant of capture. Note that the pitch bar is displaying a requirement to pitch down to stay on the glide path. This is where the trouble begins with a 2 cue flight director.

Next slide (slide 30)

This slide shows that the pilot has satisfied the pitch or glide slope command but look at the airspeed. In other words, he did it without collective. Of the pilots that we have flown in the OH-58, most of them have experienced this characteristic. Usually when asked why they didn't detect the high airspeed, they indicated they had fixation on the flight director indicator. The system is designed to allow you to do just that by reducing your cross-check requirements. This appears to work fine with a fixed wing aircraft and in a helicopter until you get into the instrument approach.

Another lesson learned with this system in the OH-58 was the adverse effects of locating the flight director indicator other than directly in front of the pilot.

Next slide (slide 31)

This slide shows the instrument as the pilot sees it. Note the parallax. When the pilot sees a centered vertical needle, it's really slightly to the right. This causes a continuous "snaking" back and forth around the trim heading. As was mentioned earlier, this is another reason why the flight accuracy was slightly reduced when the flight director was used. A third problem with the 2 cue director in the OH-58 was the inability to track with the command bars to a nondirectional beacon. This appeared to be caused by the excessive ADF needle deviations of the standard receiver installed in the aircraft. It is a significant problem which must be corrected in order to properly use the flight director in this mode. (slide off)

We have pointed out in the past few minutes, a system which is a significant improvement over the standard helicopter panel, but it has some adverse side effects which must be considered. We think we see one solution to our flight instrumentation problems with the new 3 cue system that arrived for testing recently.

Next slide (slide 32)

What I would like to do is show the differences in this second-generation system compared to the 2 cue previously discussed. The flight director indicator has the same cross bar arrangement and, in addition, there is a small "doughnut" on the left side of the instrument that provides a collective command. This portion of the unit provides commands for altitude hold, glide slope and climbs and descents which can be selected on the vertical speed selector. Any airspeed can be selected within the envelope of the aircraft and the horizontal bar now commands the pitch attitude to retain the airspeed. Now let's look at the operation.

Next slide (slide 33)

This slide shows a situation where the pilot has allowed the aircraft to deviate again. This time essentially everything he needs to know to recover is displayed on one instrument. The commands are up collective for altitude, and roll left of heading. Let us take the same case with the ILS course.

Next slide (slide 34)

The aircraft is on the localizer beam and approaching glide slope capture.

Next slide (slide 35)

The glide slope has been captured; note the command for down collective. Airspeed and pitch attitude are at trim. The 3 cue system eliminates the problem with airspeed control. Probably the most enhancing feature of this unit is the automatic deceleration mode. This feature initiates a deceleration on any approach when the radar altimeter reaches 400 feet. The system will continue the deceleration until the aircraft reaches 100 feet, at which time the airspeed will stay at 40 knots. This feature can be used on ILS, VOR, and ADF approaches. In addition, the heading hold mode and a descent mode can be selected and an approach can be made without any ground facility. The latter case appears to have tremendous potential in a tactical environment.

Next slide (slide 36)

This slide shows the deceleration being initiated while on its ILS approach. Note the entry airspeed, radar altimeters, and vertical speed.

Next slide (slide 37)

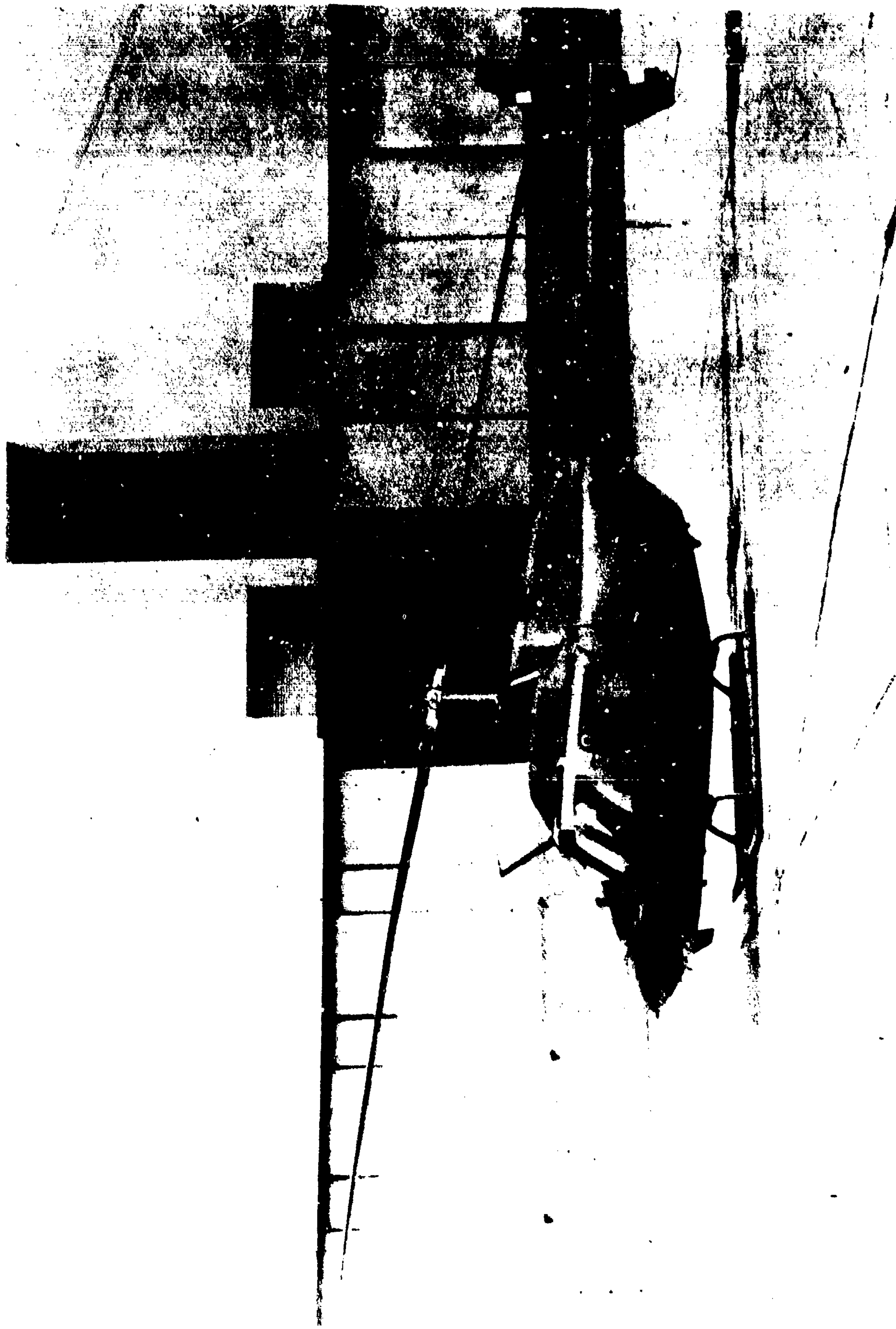
Note the radar altimeter, the pitch commands, and the airspeed.

Next slide (slide 38)

Note the airspeed and the pitch command which indicated the nose should be lowered to regain 40 knots. Also note the radar altimeter and the decision lights. As we said earlier, this is a feature that could certainly enhance the capability of the helicopter in a tactical environment.

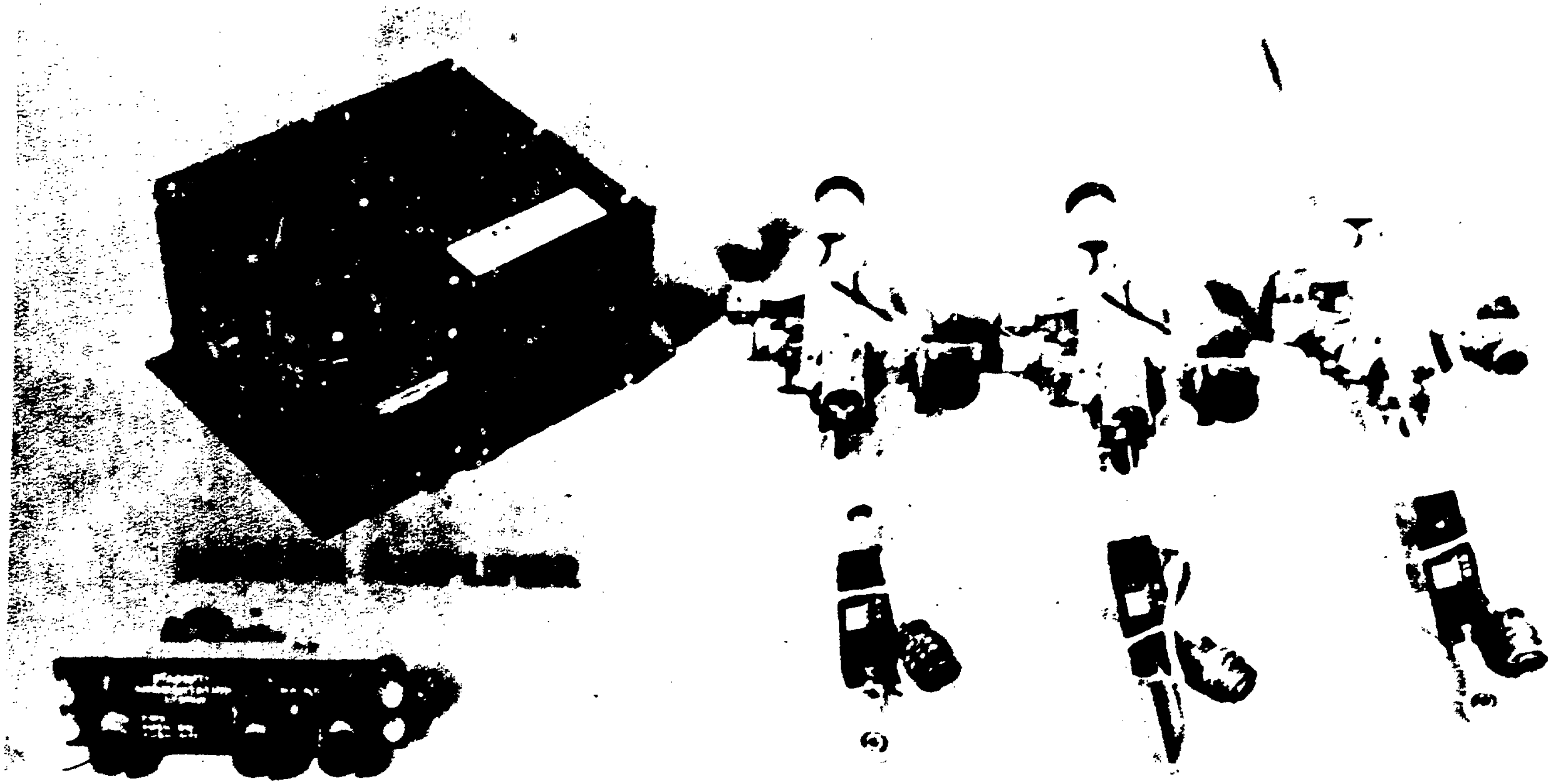
Slide off

SUMMARY We have only highlighted the two flight directors, both of which have other features. The 3 cue system is now at ASTA and we have only done preliminary testing; however, we have recorded significant improvements in flight accuracy during an ILS approach. No doubt it will have some problem areas but at first glance it appears to be a quantum jump in flight director technology. Are there any questions pertaining to either of the flight directors of the OH-58 instrument evaluation?



SLIDE 1.

SCAS COMPONENTS



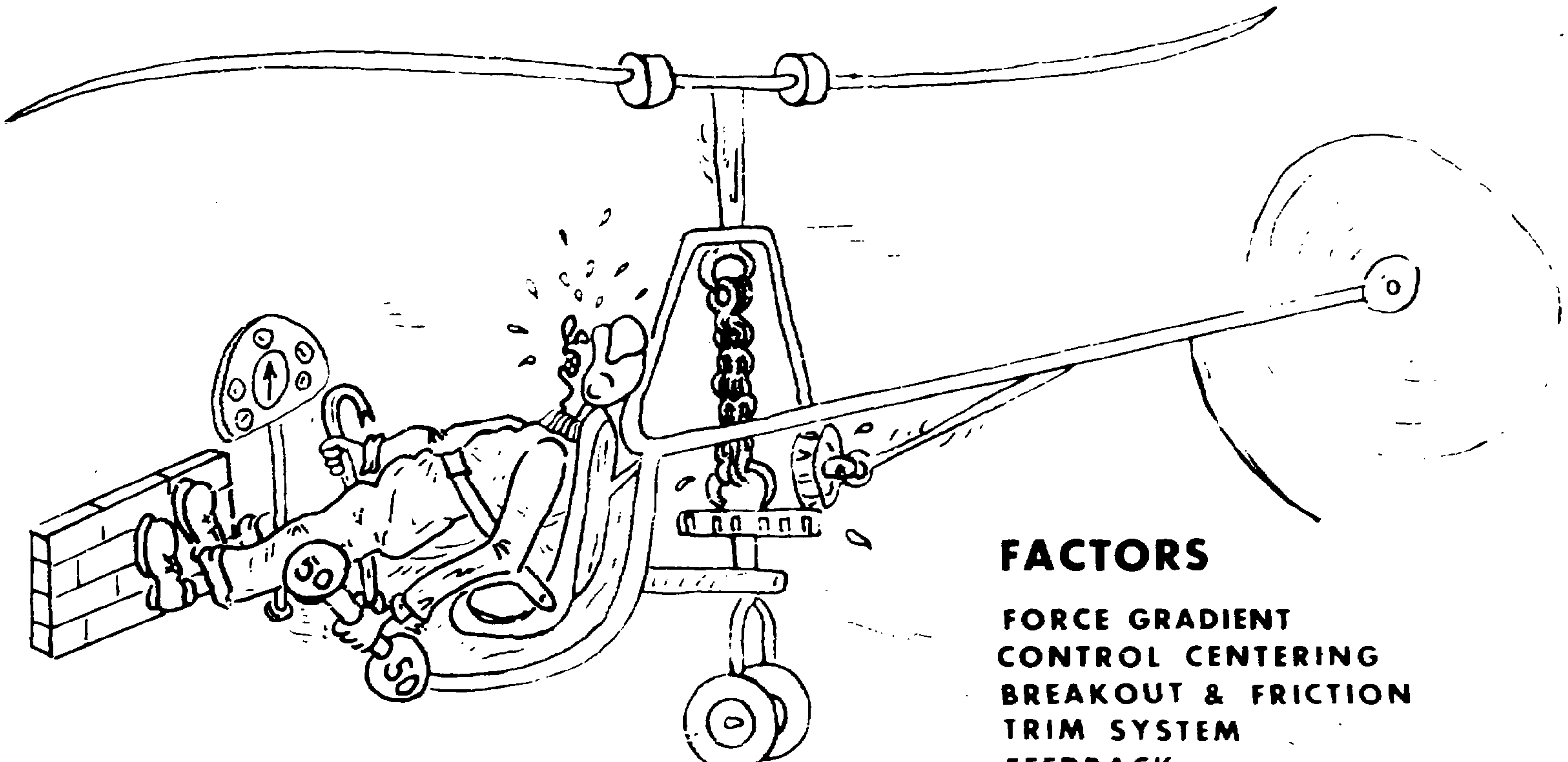
SLIDE 2.

OH-58A
MAJOR TEST AREAS

DISCREPANCIES	SATISFACTORY	TEST
X		CONTROL SYSTEM CHARACTERISTICS
X		CONTROLLABILITY
	X	CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
	X	STATIC LONGITUDINAL STABILITY
	X	STATIC LATERAL-DIRECTIONAL STABILITY
X	X	DYNAMIC LONGITUDINAL STABILITY
		DYNAMIC LATERAL-DIRECTIONAL STABILITY
X	X	IFR AUTOROTATIONAL ENTRY CHARACTERISTICS
		COCKPIT EVAUATION
X		PILOT WORKLOAD/FLIGHT PATH ACCURACY

SLIDE 3.

CONTROL SYSTEM CHARACTERISTICS

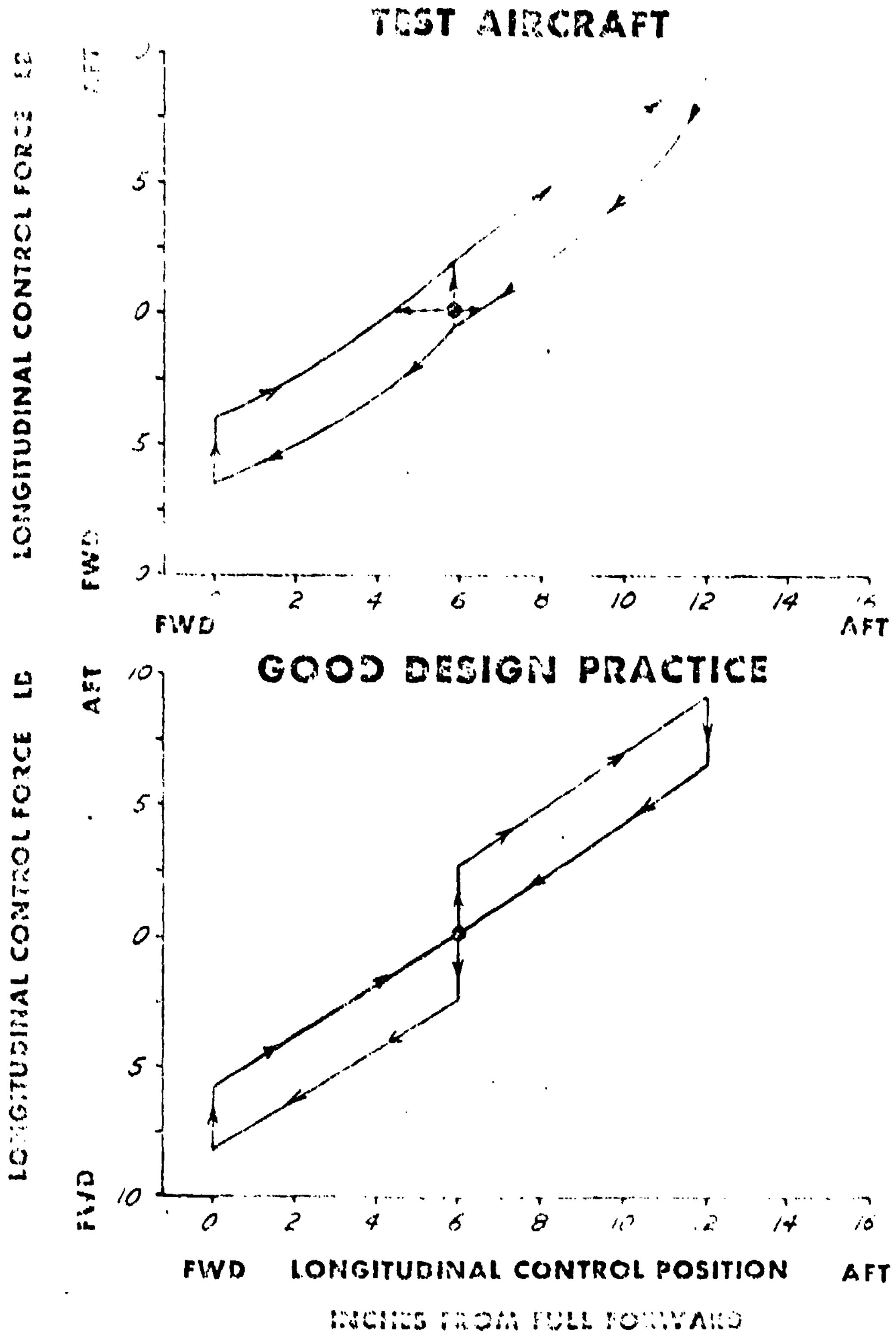


FACTORS

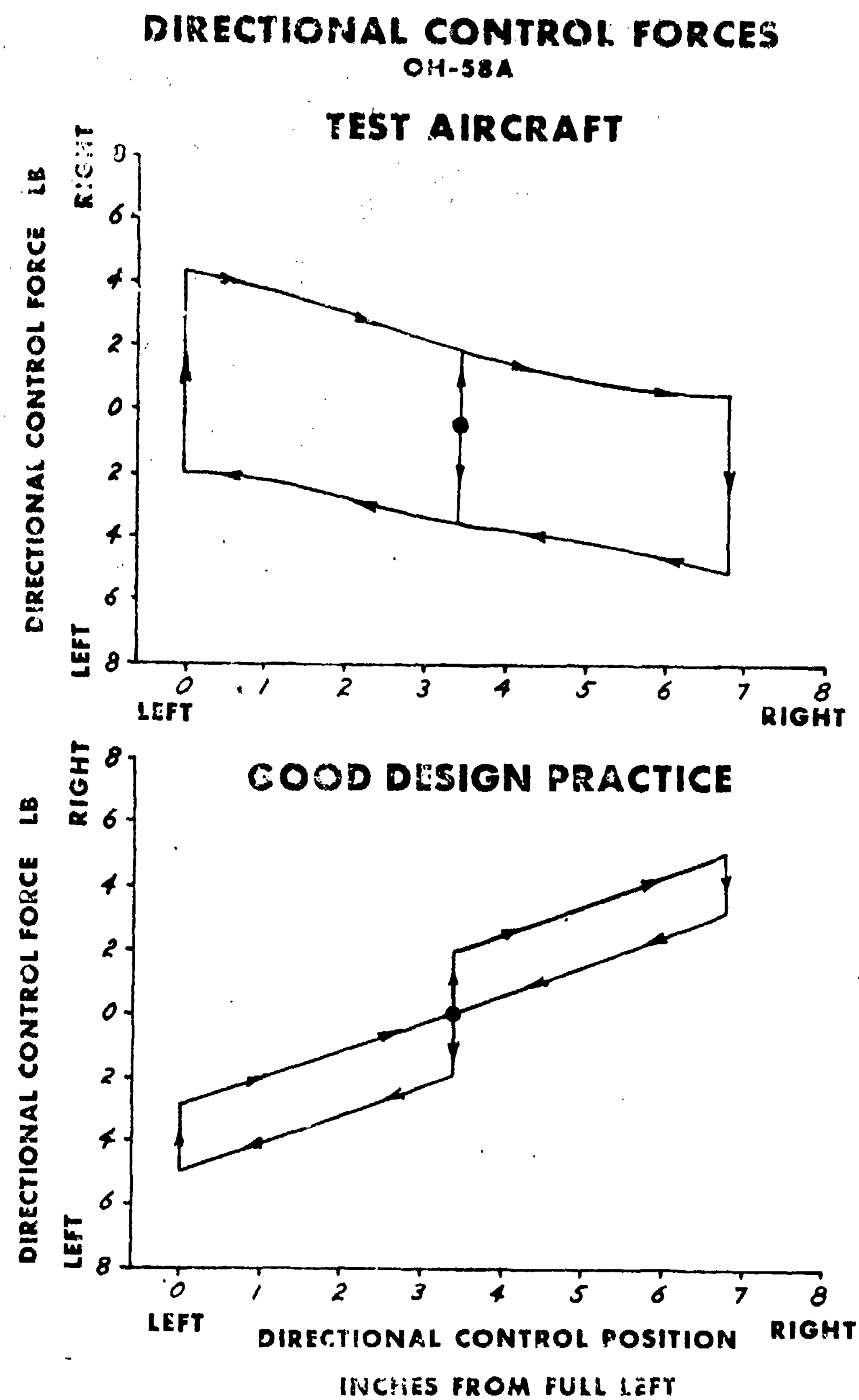
FORCE GRADIENT
CONTROL CENTERING
BREAKOUT & FRICTION
TRIM SYSTEM
FEEDBACK

SLIDE 4.

LONGITUDINAL CONTROL FORCES
OH-58A



SLIDE 5.



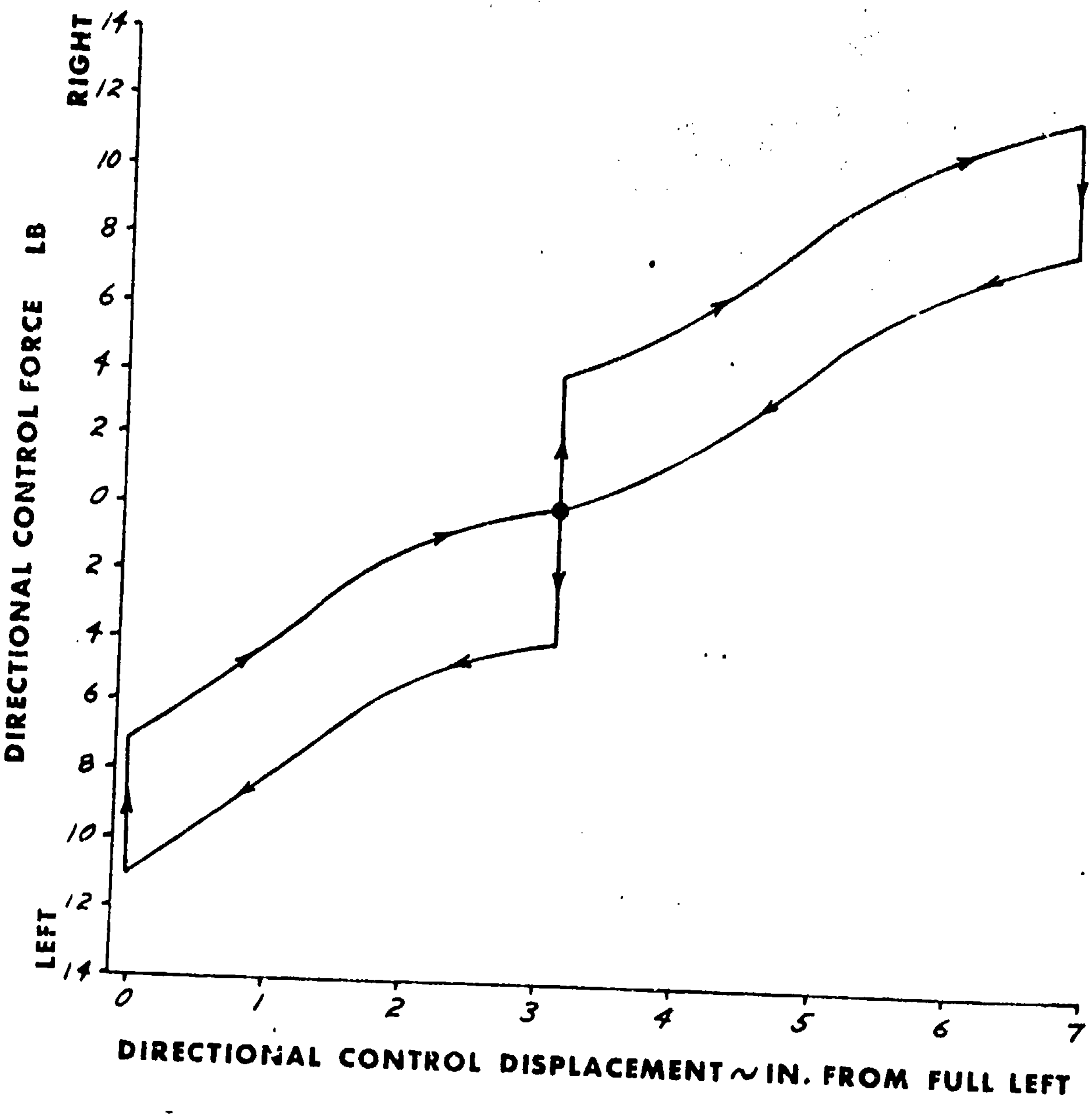
DIRECTIONAL CONTROL FORCES
OH-58A
TEST AIRCRAFT
DIRECTIONAL CONTROL FORCE LB
RIGHT
LEFT
8
6
4
2
0
2
4
6
8
0
1
2
3
4
5
6
7
8
LEFT
RIGHT
GOOD DESIGN PRACTICE
DIRECTIONAL CONTROL FORCE LB
RIGHT
LEFT
DIRECTIONAL CONTROL POSITION
INCHES FROM FULL LEFT

SLIDE 6.

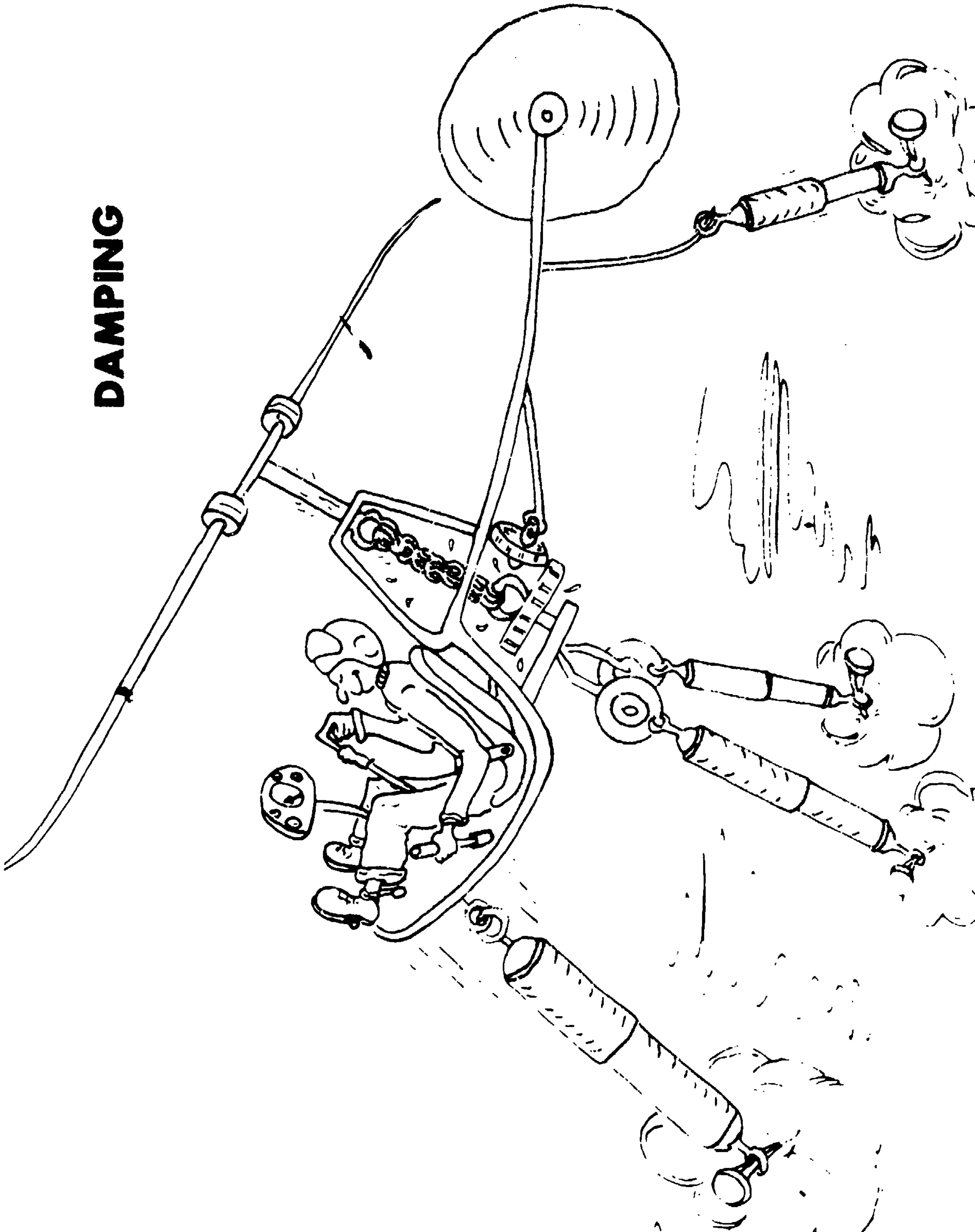
DIRECTIONAL CONTROL FORCES

OH-58A

MODIFIED FORCE GRADIENT

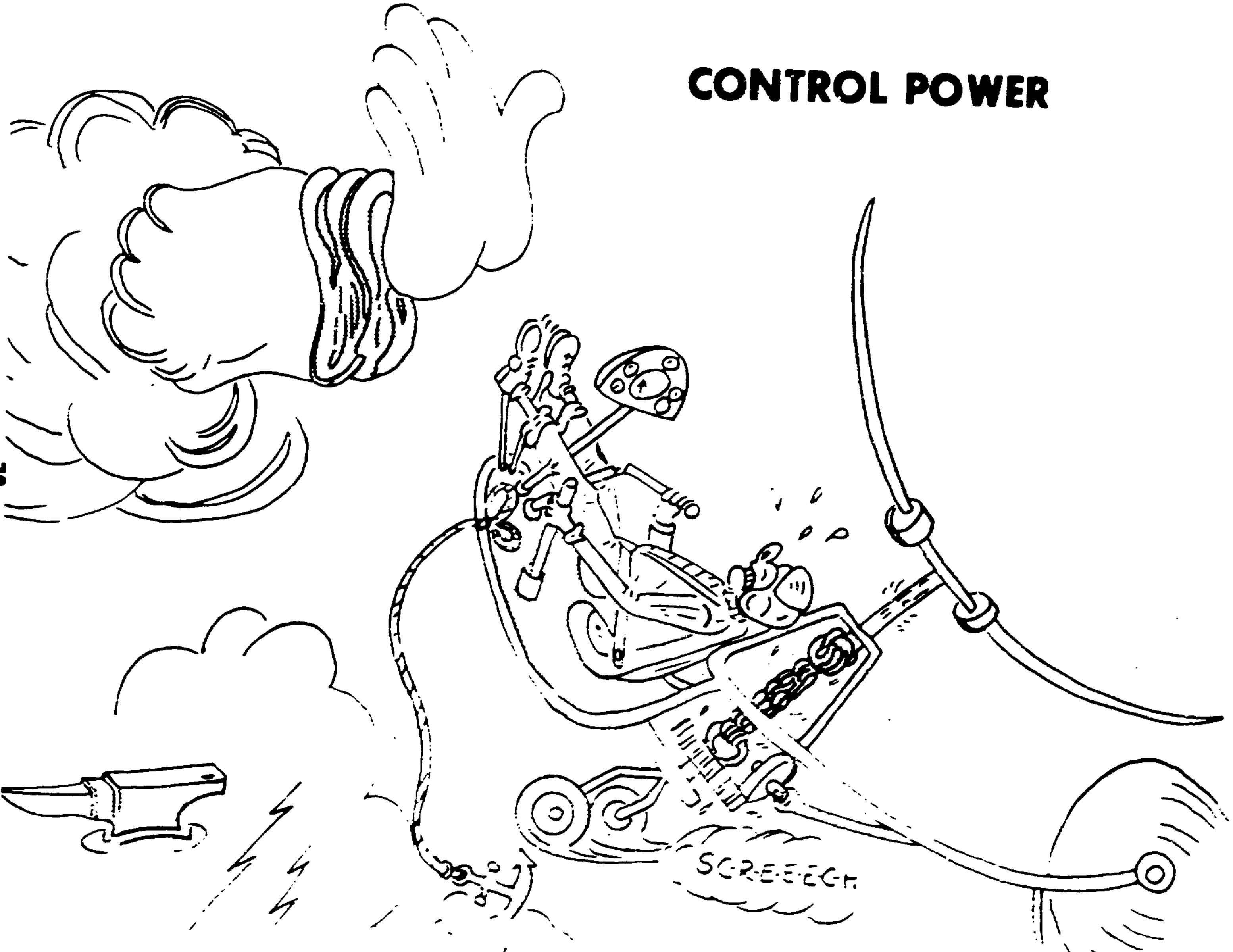


DAMPING



SLIDE 8.

CONTROL POWER



SLIDE 9.

OH-58A HOVERING CONTROLLABILITY CHARACTERISTICS

CONTROL POWER (degrees)

AXIS	REQUIRED	ACTUAL
LONGITUDINAL	4.7	4.7
LATERAL	2.0	2.0
DIRECTIONAL	7.0	19.5

ANGULAR VELOCITY DAMPING (ft-lb/rad/sec)

AXIS	REQUIRED	ACTUAL
LONGITUDINAL	3010	2496
LATERAL	2193	995
DIRECTIONAL	4575	APPROACHING ZERO

NOTE: (1) LONGITUDINAL AND DIRECTIONAL ANGULAR DISPLACEMENT AT THE END OF ONE SEC FOR A ONE-INCH CONTROL DISPLACEMENT

(2) LATERAL ANGULAR DISPLACEMENT AT THE END OF ½ SEC FOR A ONE-INCH CONTROL DISPLACEMENT

SLIDE 10.

OH-58A RATE DAMPING CHARACTERISTICS

AXIS	MIL-H-8501A	SCAS OFF	SCAS ON
PITCH	3011	2496	3245
ROLL	2193	995	1571
YAW	4573	APPROACHING ZERO	4037

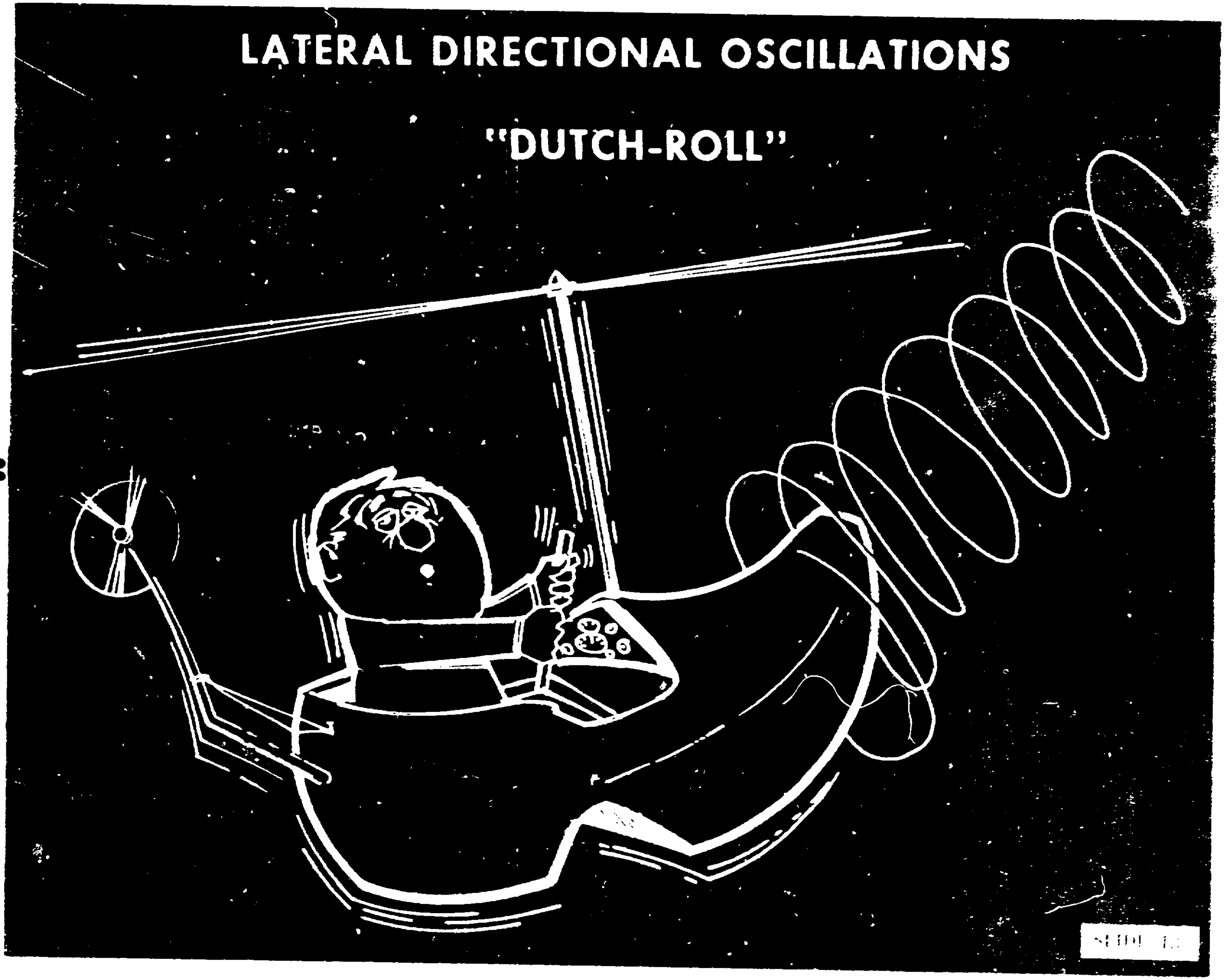
SLIDE 11.

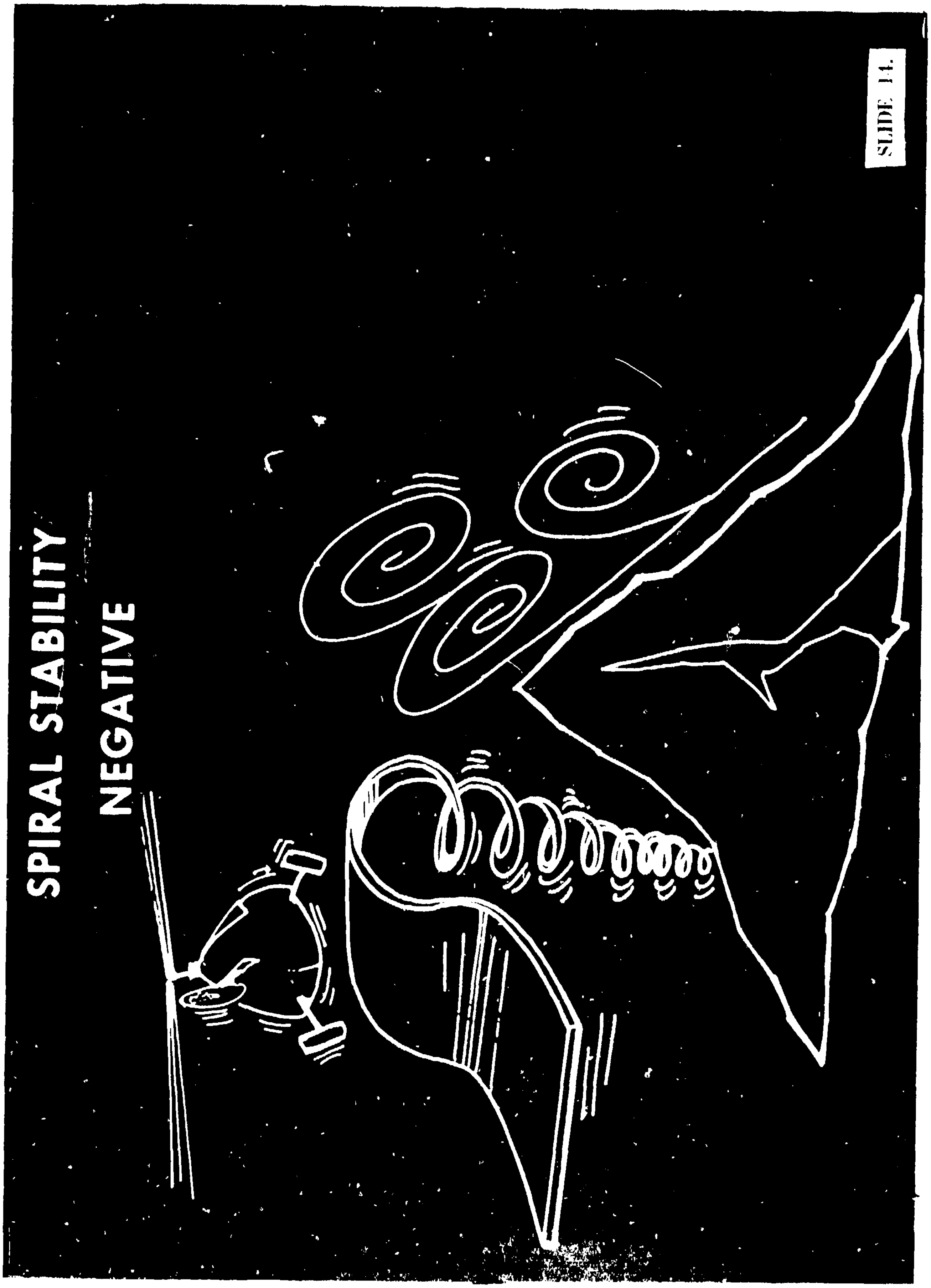
DYNAMIC

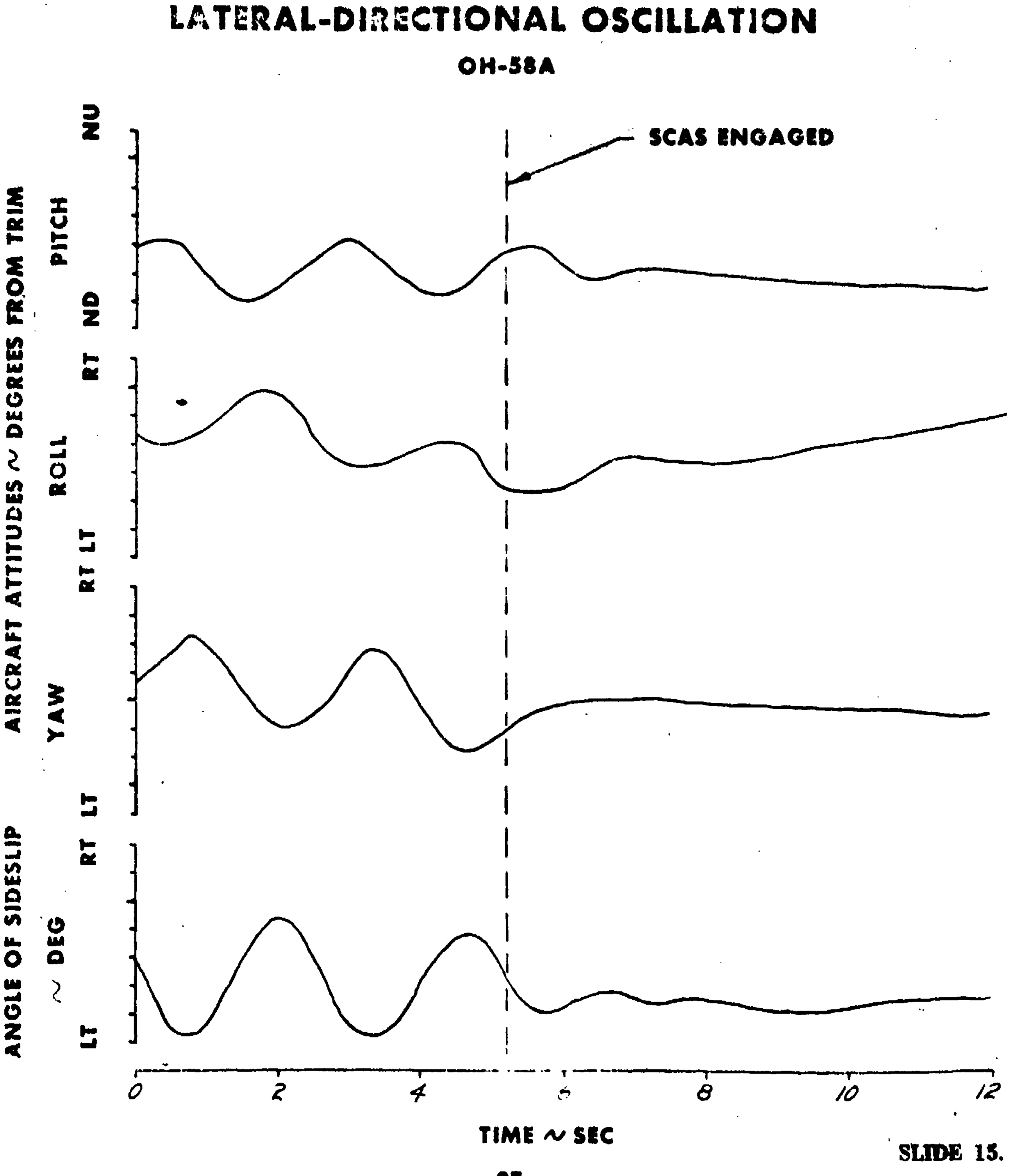
LATERAL-DIRECTIONAL

STABILITY

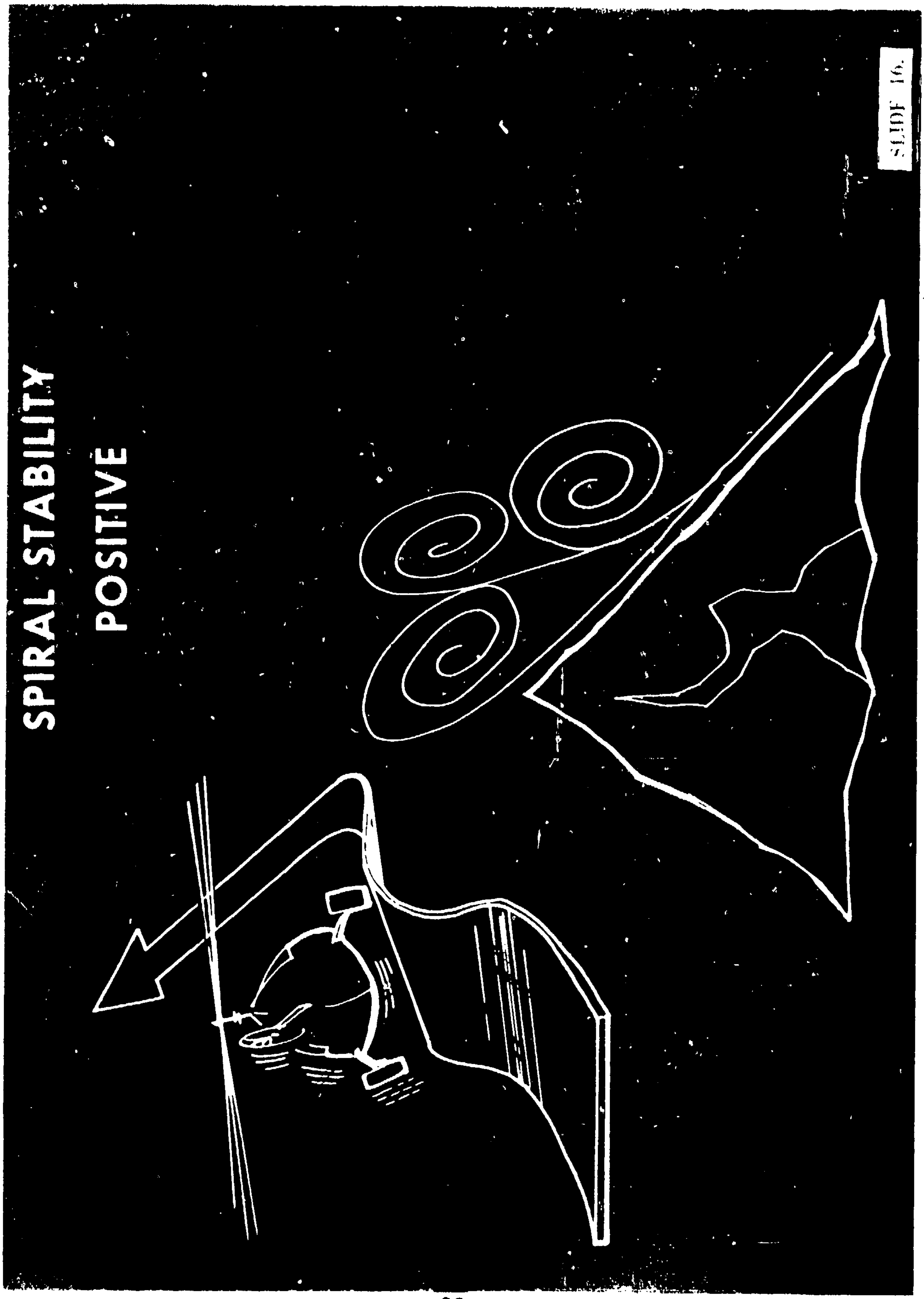
SLIDE 12.

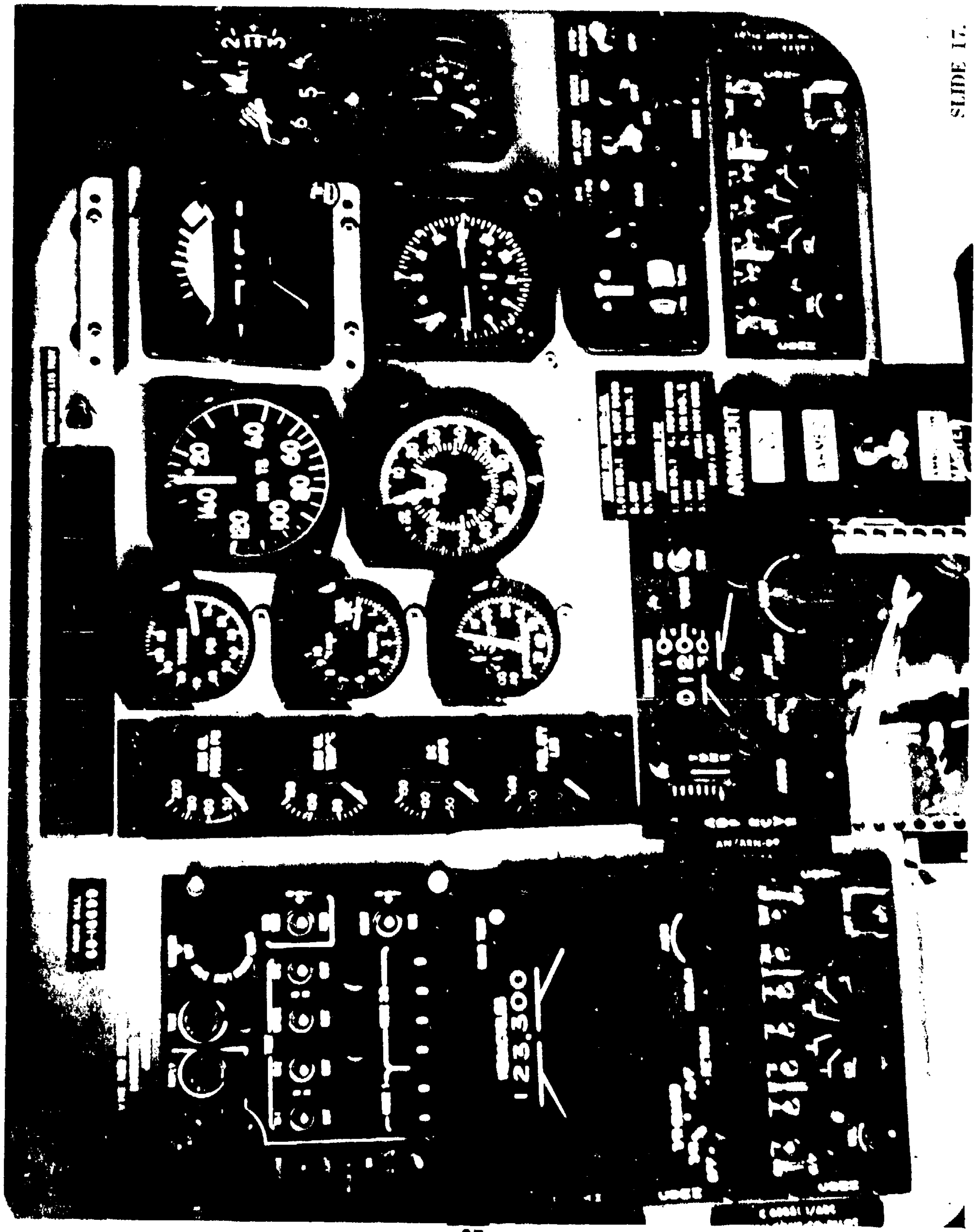

LATERAL DIRECTIONAL OSCILLATIONS
"DUTCH-ROLL"


SPIRAL STABILITY
NEGATIVE
SLIDE 14.

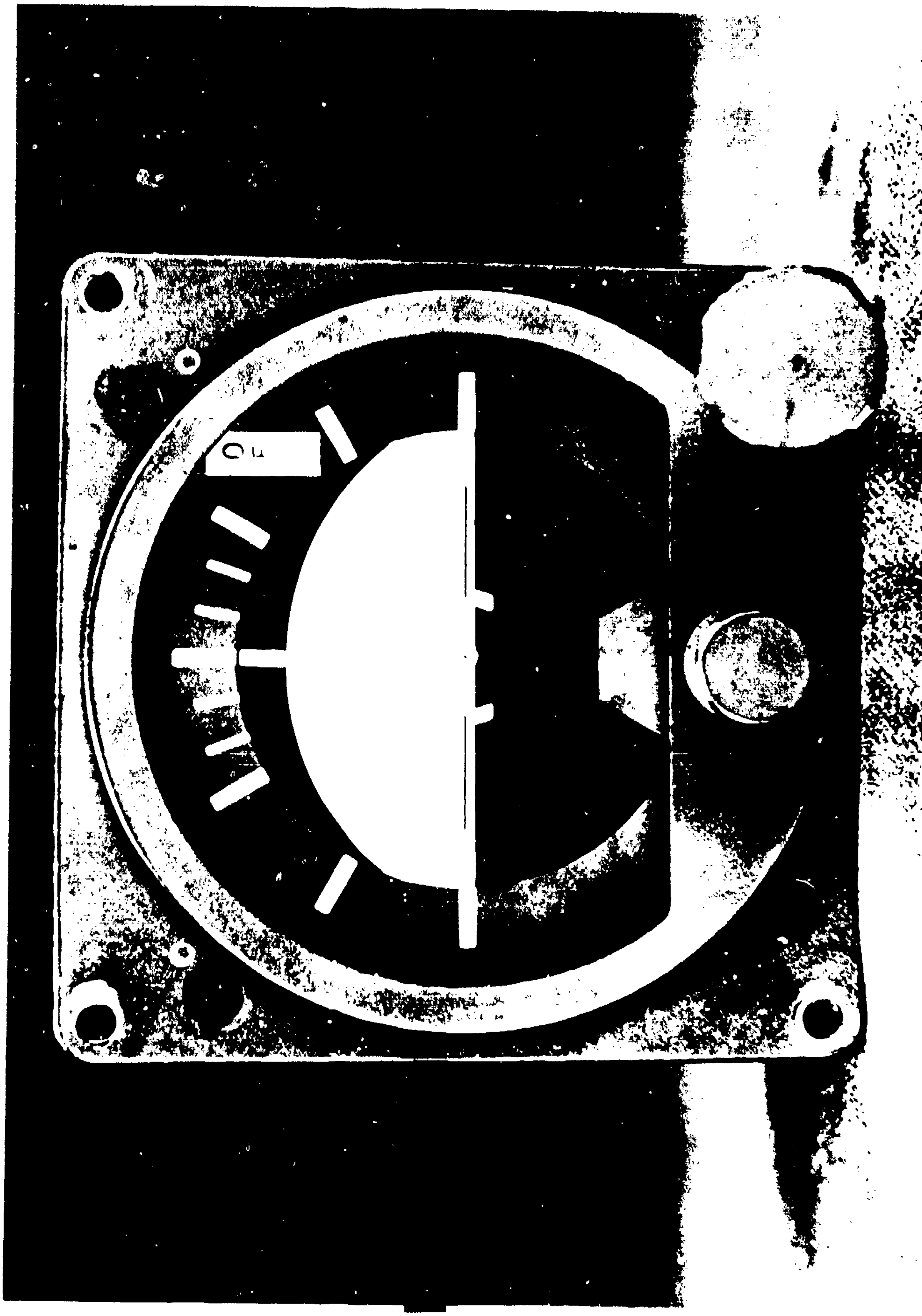

LATERAL-DIRECTIONAL OSCILLATION
OH-58A
SCAS ENGAGED
AIRCRAFT ATTITUDES ~ DEGREES FROM TRIM
PITCH
NU
ND
ROLL
RT
LT
YAW
RT
LT
ANGLE OF SIDESLIP ~ DEG
RT
LT
0
2
4
6
8
10
12
TIME ~ SEC

SLIDE 15.


SPIRAL STABILITY
POSITIVE
SLIDE 16.



SLIDE 17.



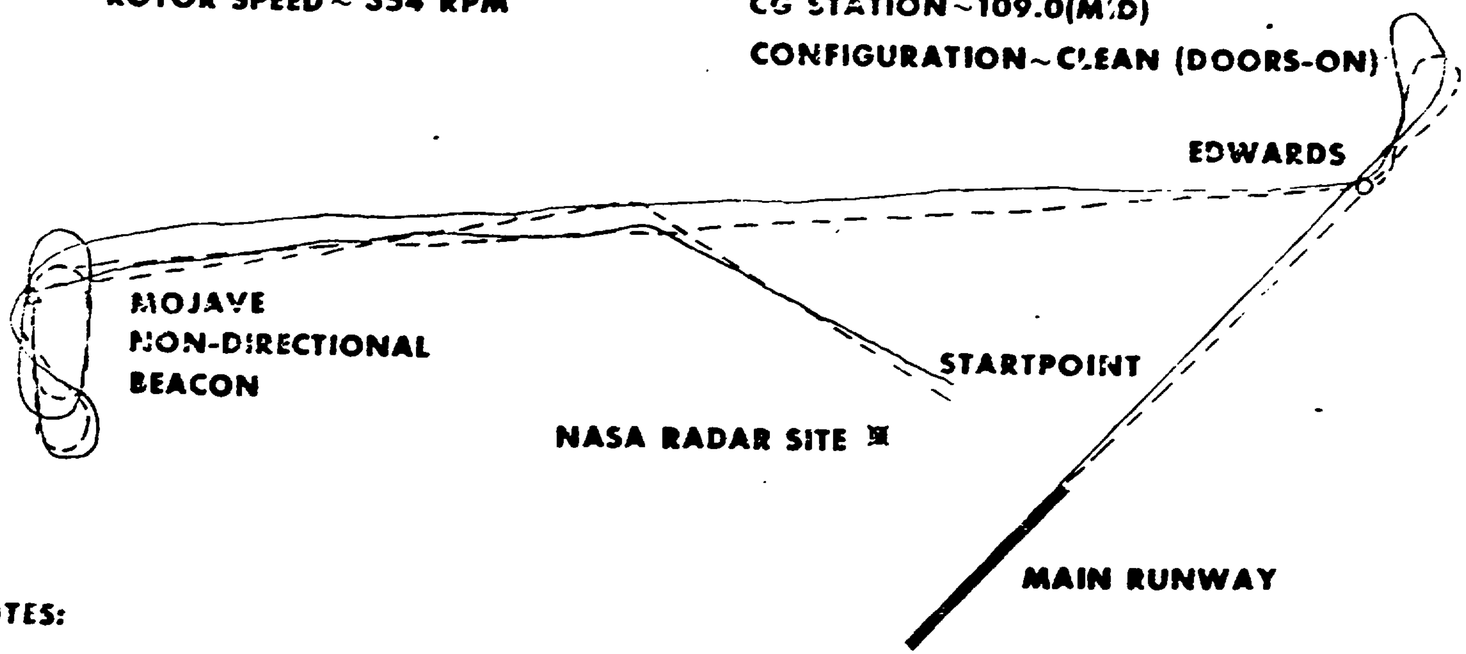
SLIDE 18.

TOP

IFR MISSION PROFILE WITH FLIGHT DIRECTOR

CALIBRATED AIRSPEED ~ 88 KTS
ROTOR SPEED ~ 354 RPM

GROSS WEIGHT ~ 2800 LBS (AVG)
CG STATION ~ 109.0 (MID)
CONFIGURATION ~ CLEAN (DOORS-ON)



NOTES:

- BLACK LINE REPRESENTS THE THEORETICAL NO WIND MISSION PROFILE ENVELOPE
- RED LINE REPRESENTS THE ACTUAL MISSION PROFILE ENVELOPE
- WEATHER CONDITIONS, SURFACE WINDS CALM WINDS AT 7000 FEET 5KTS AT 115° MAGNETIC
- SCALE 1 INCH 2 NAUTICAL MILES

SLIDE 19.

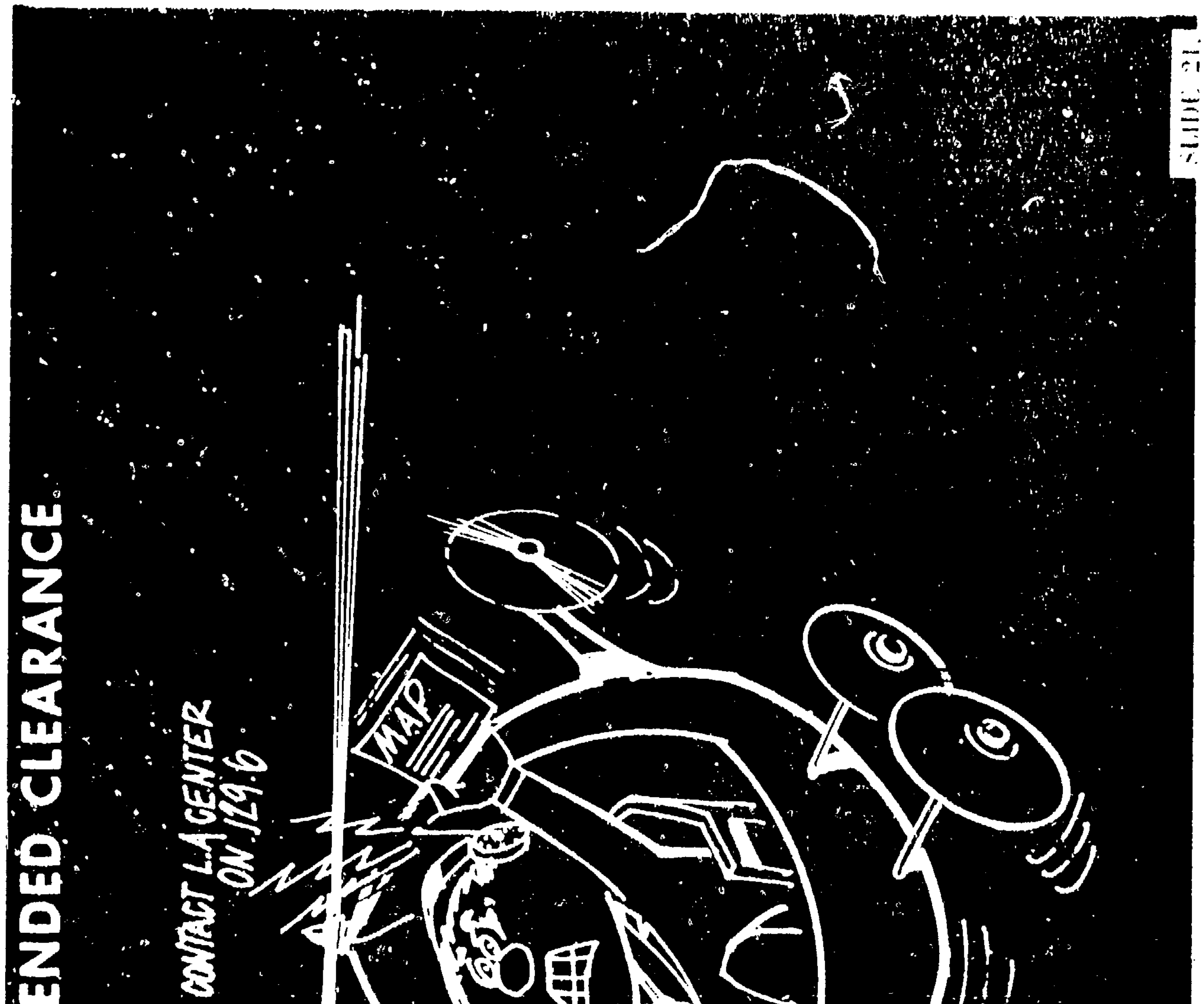
PILOT WORKLOAD COMPARISON

INCREASED CONTROL USAGE, VFR TO IFR

OH-58A

CONFIGURATION	FLIGHT CONDITION	PERCENT INCREASE OF CONTROL REVERSALS, VFR TO IFR ~ PERCENT
BASIC OH-58A	LEVEL CRUISE	65.5
OH-58A WITH SPERRY FDS	LEVEL CRUISE	50.0

SLIDE 20.


THE AMENDED CLEARANCE
CONTACT L.A. CENTER ON 129.6
MAP
SLIDE 21.

PILOT WORKLOAD
AND FLIGHT ACCURACY COMPARISON

TEST CONDITIONS	AIRSPEED ERROR (KT) (1)	ALTITUDE ERROR (FT) (2)	HEADING ERROR (DEG) (3)	PILOT WORKLOAD REDUCTION (PERCENT) (4)
SCAS OFF VFR	2.2	33	3.3	BASELINE WORKLOAD
SCAS ON VFR	2.2	29	1.6	56
SCAS ON IFR	2.6	32	2.0	48
SCAS/FDS ON IFR	2.9	34	3.4	43

(1) STANDARD DEVIATION FROM TRIM AIRSPEED

(2) STANDARD DEVIATION FROM TRIM ALTITUDE

(3) STANDARD DEVIATION FROM TRIM HEADING

(4) PERCENT REDUCTION FROM SCAS OFF VFR

SLIDE 22.

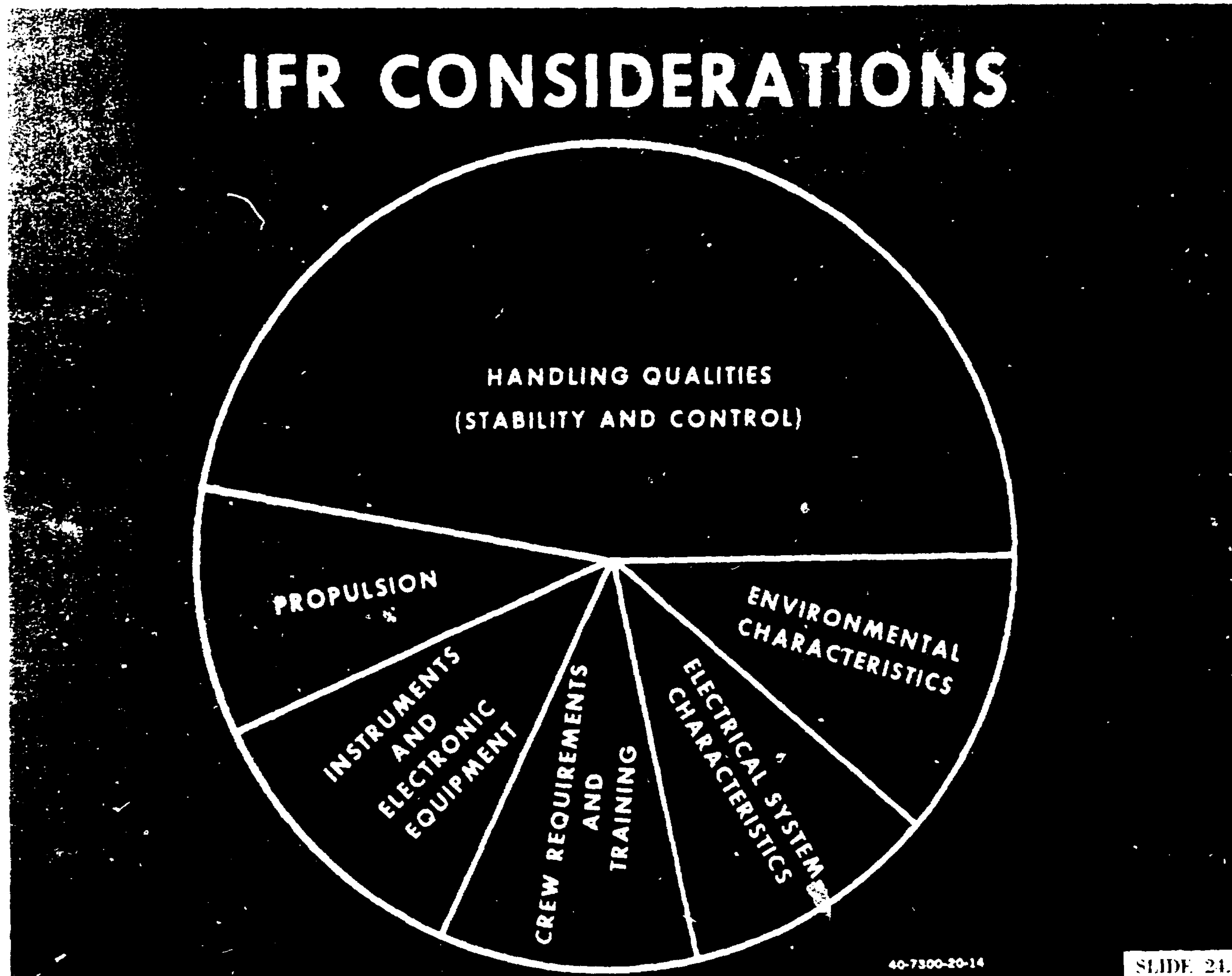
700

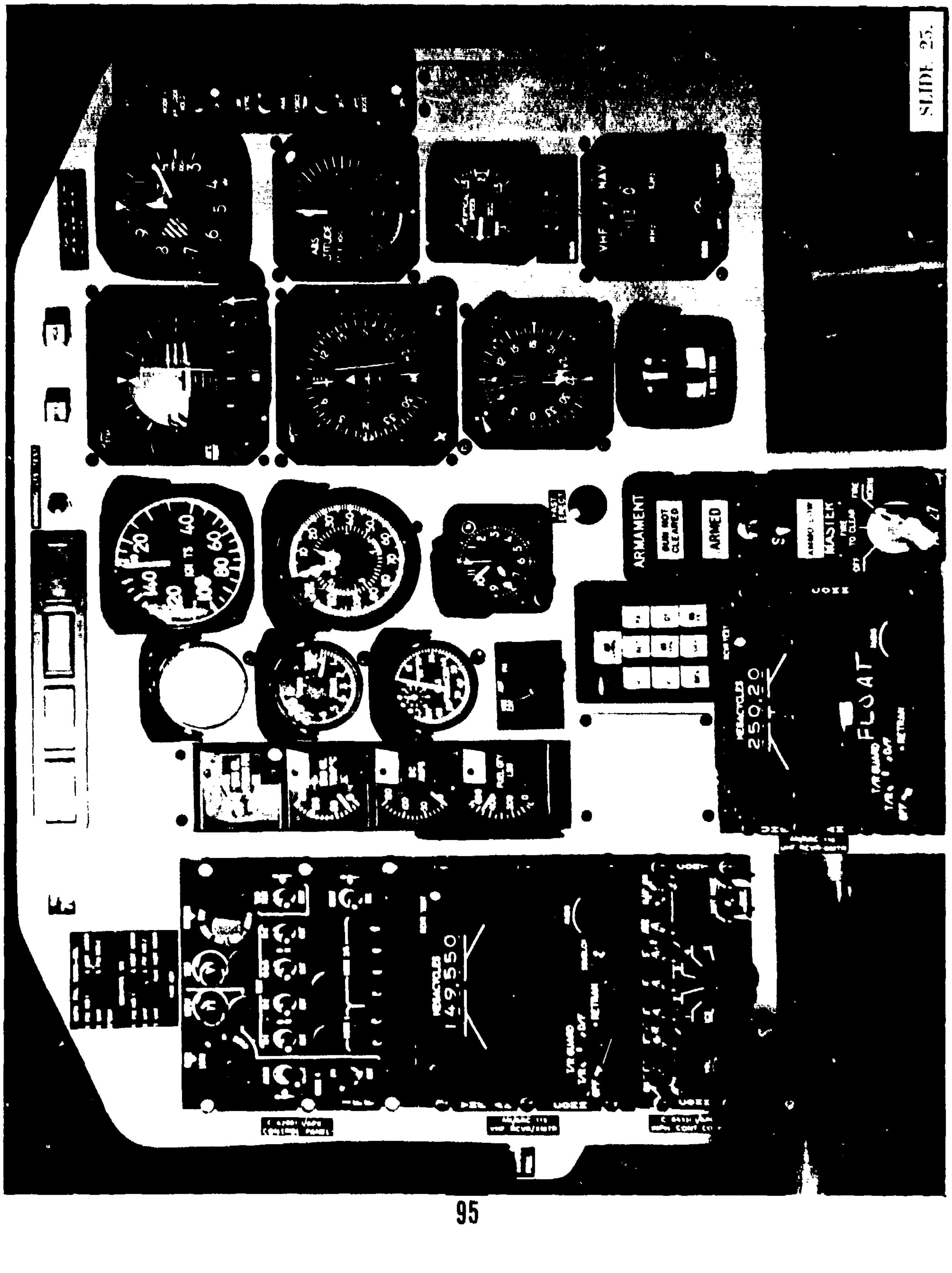
SUMMARY

OH-58A CORRECTIONS REQUIRED FOR IFR FLIGHT

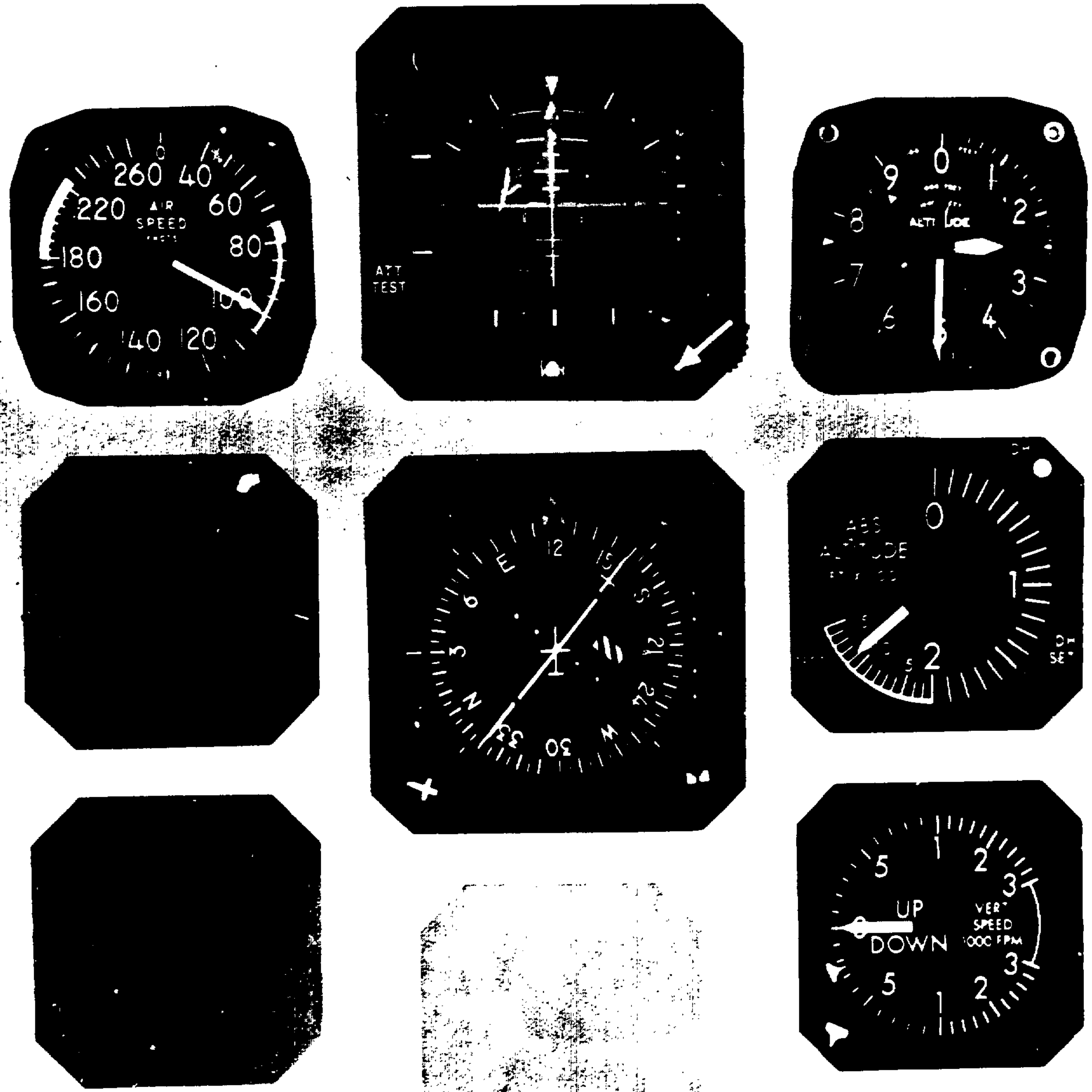
- **STABILITY AUGUMENTATION**
- **CONTROL CENTERING**
- **IMPROVED VERTICAL SPEED AND ATTITUDE INDICATORS**
- **ADDITIONAL NAVIGATION RADIOS**

SLIDE 23.

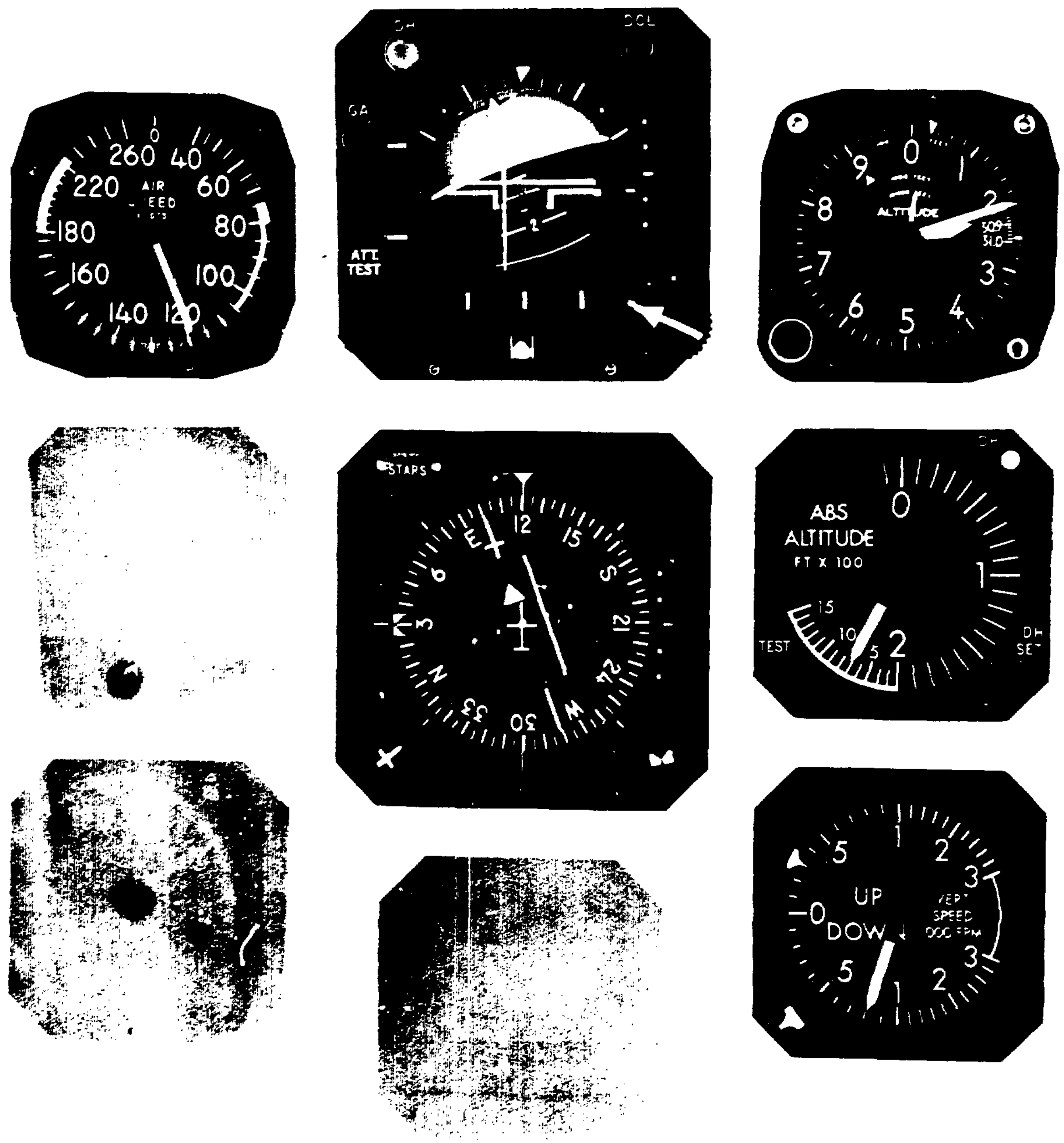

IFR CONSIDERATIONS
HANDLING QUALITIES
(STABILITY AND CONTROL)
ENVIRONMENTAL CHARACTERISTICS
ELECTRICAL SYSTEM CHARACTERISTICS
CREW REQUIREMENTS AND TRAINING
INSTRUMENTS AND ELECTRONIC EQUIPMENT
PROPULSION
40-7300-20-14
SLIDE 24.



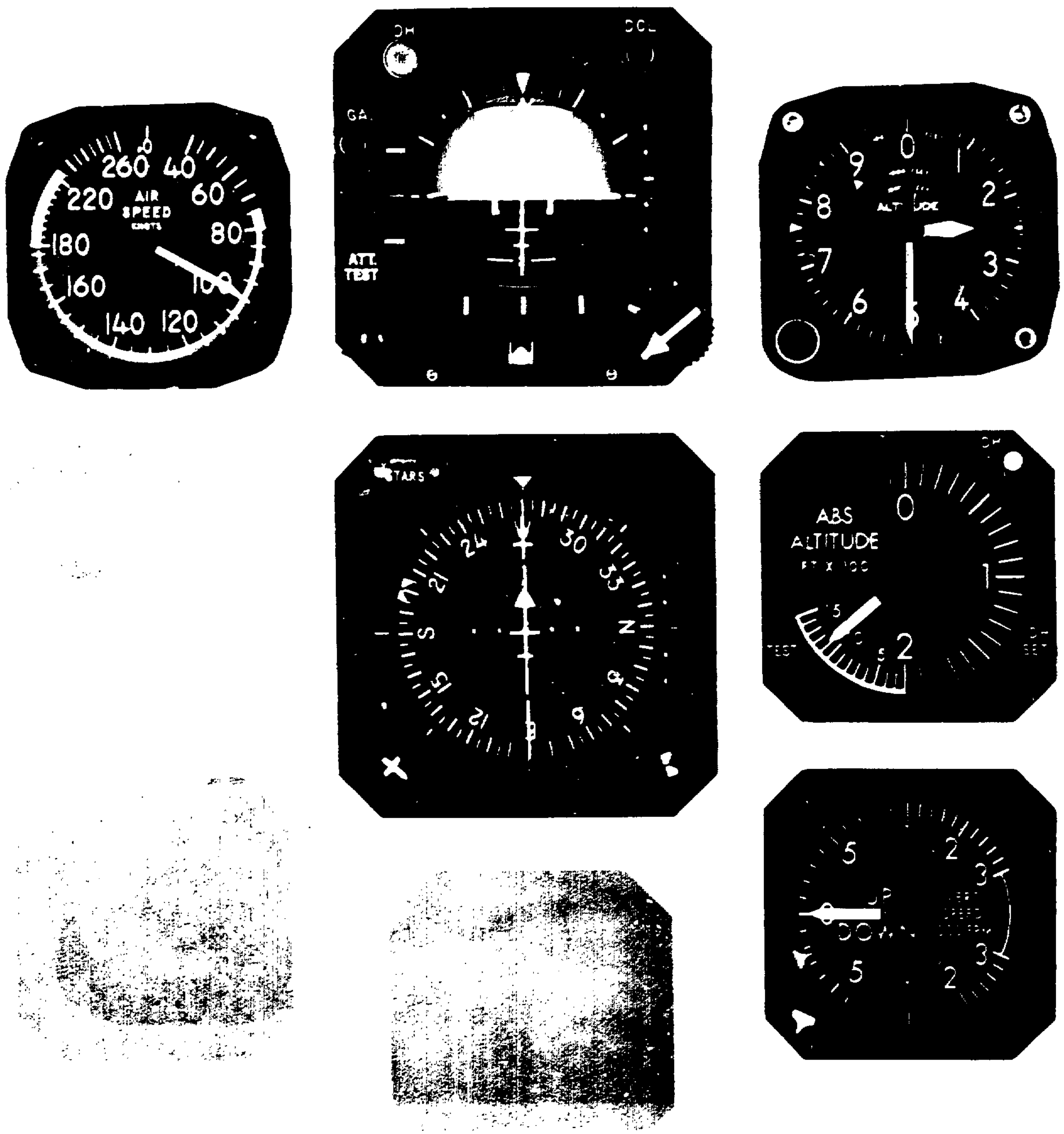
SLIDE 25.


AIR SPEED
ATT TEST
ALTITUDE
ABS ALTITUDE
DH SET
UP
DOWN
VERT SPEED 1000 FPM

SLIDE 26.

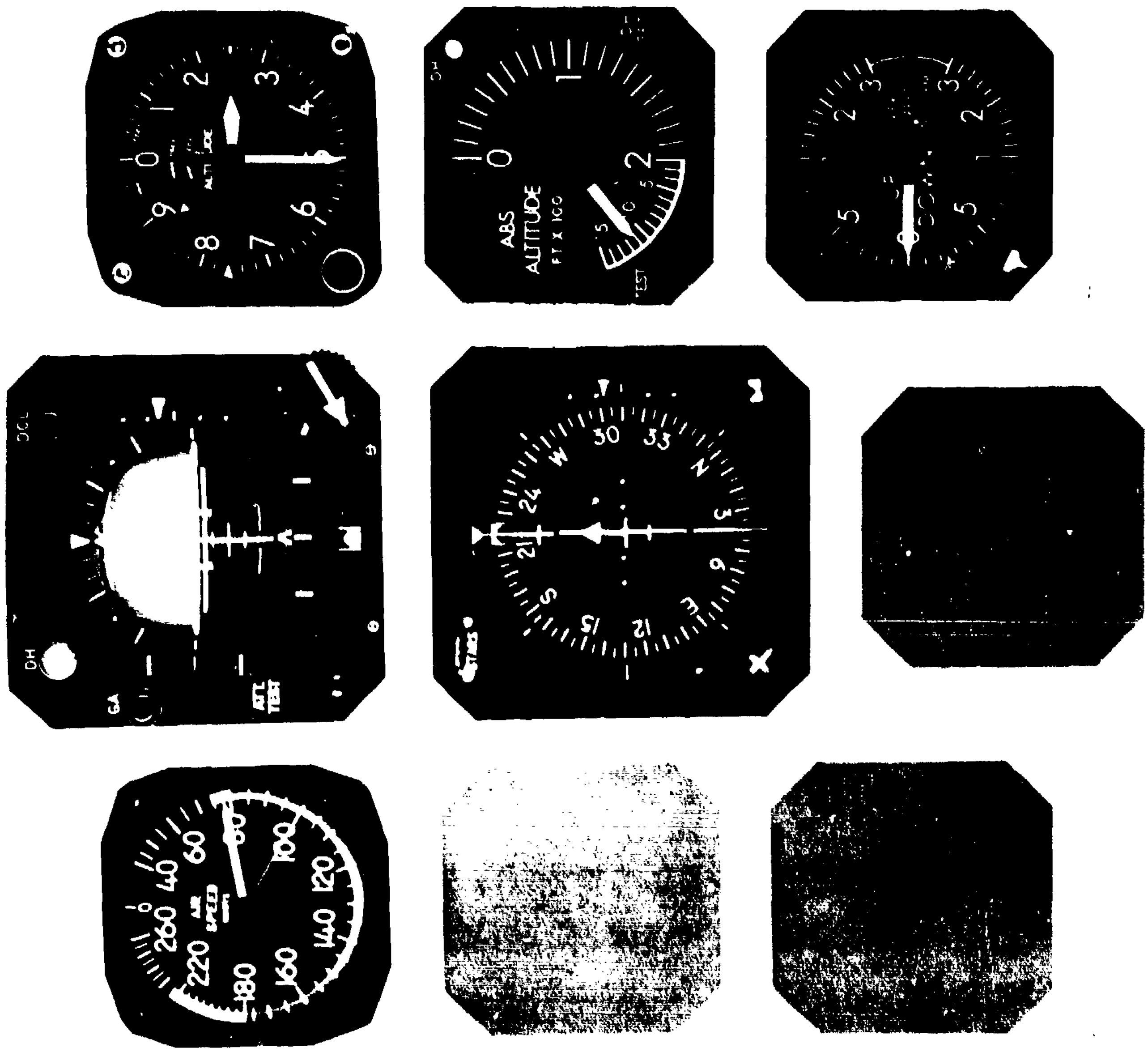

AIR SPEED
ATT. TEST
ALTITUDE
STAPS
ABS ALTITUDE FT X 100
TEST
DH SET
UP
DOWN
VERT SPEED

SLIDE 27.

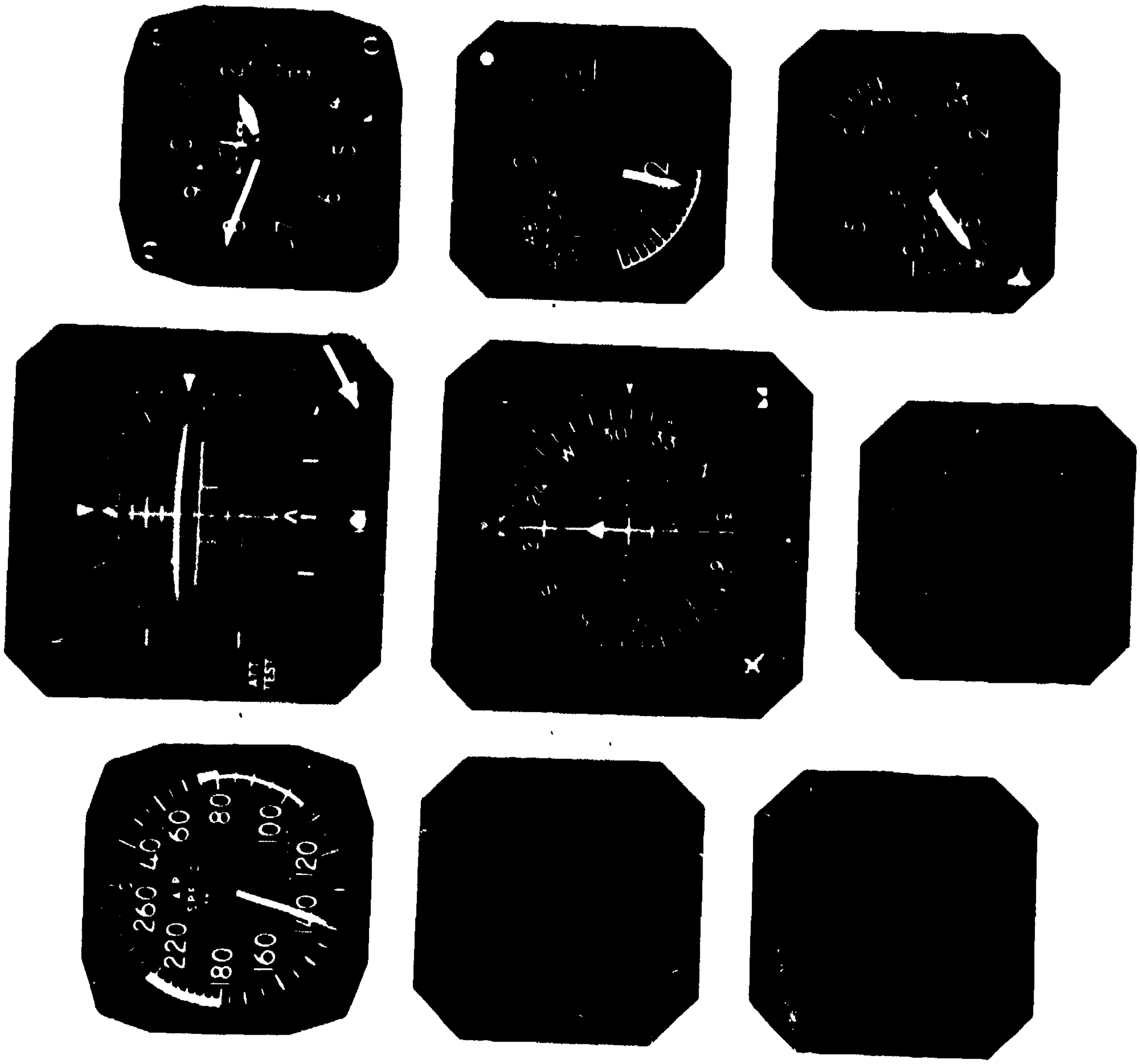


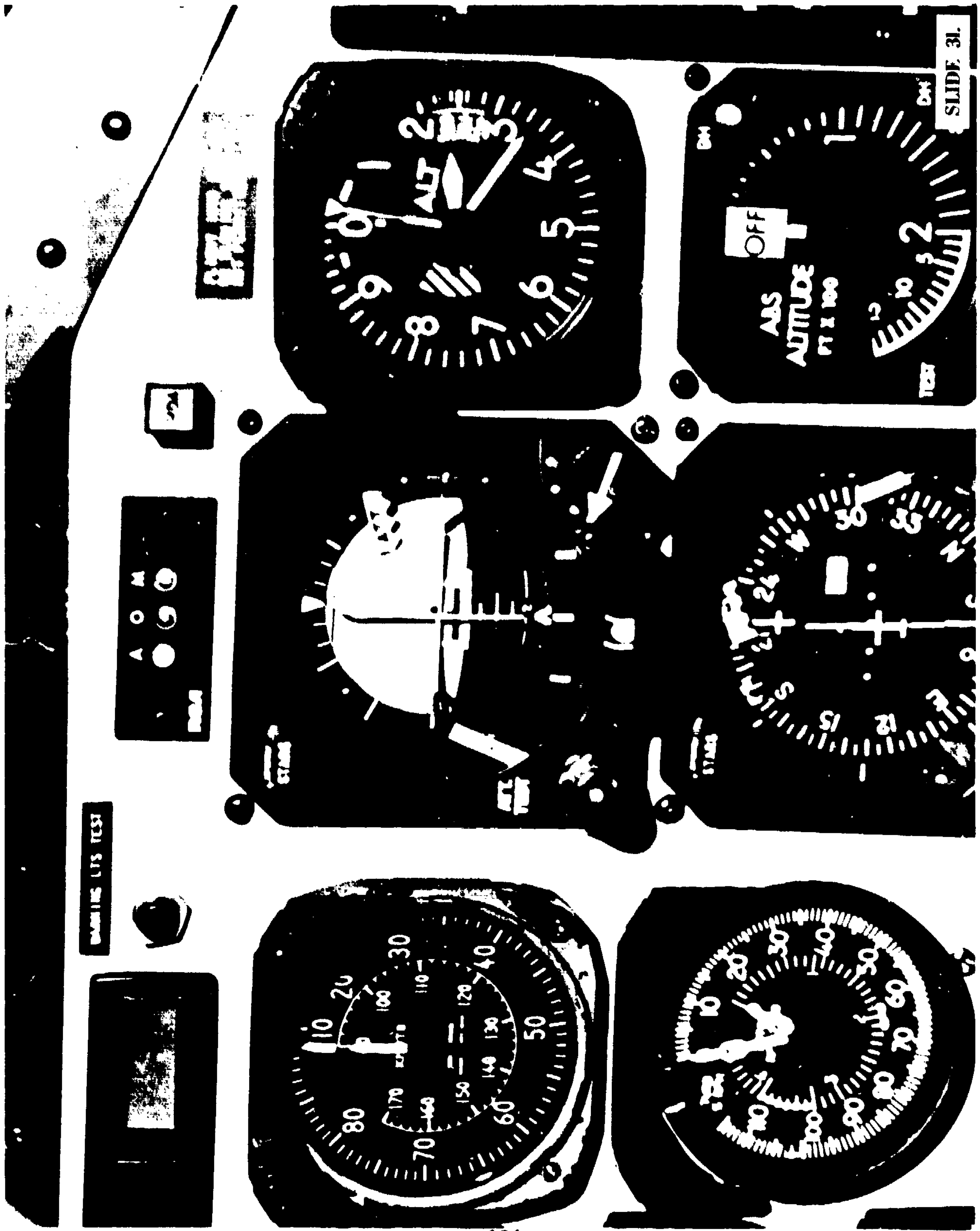
SLIDE 28.

SLIDE 29.

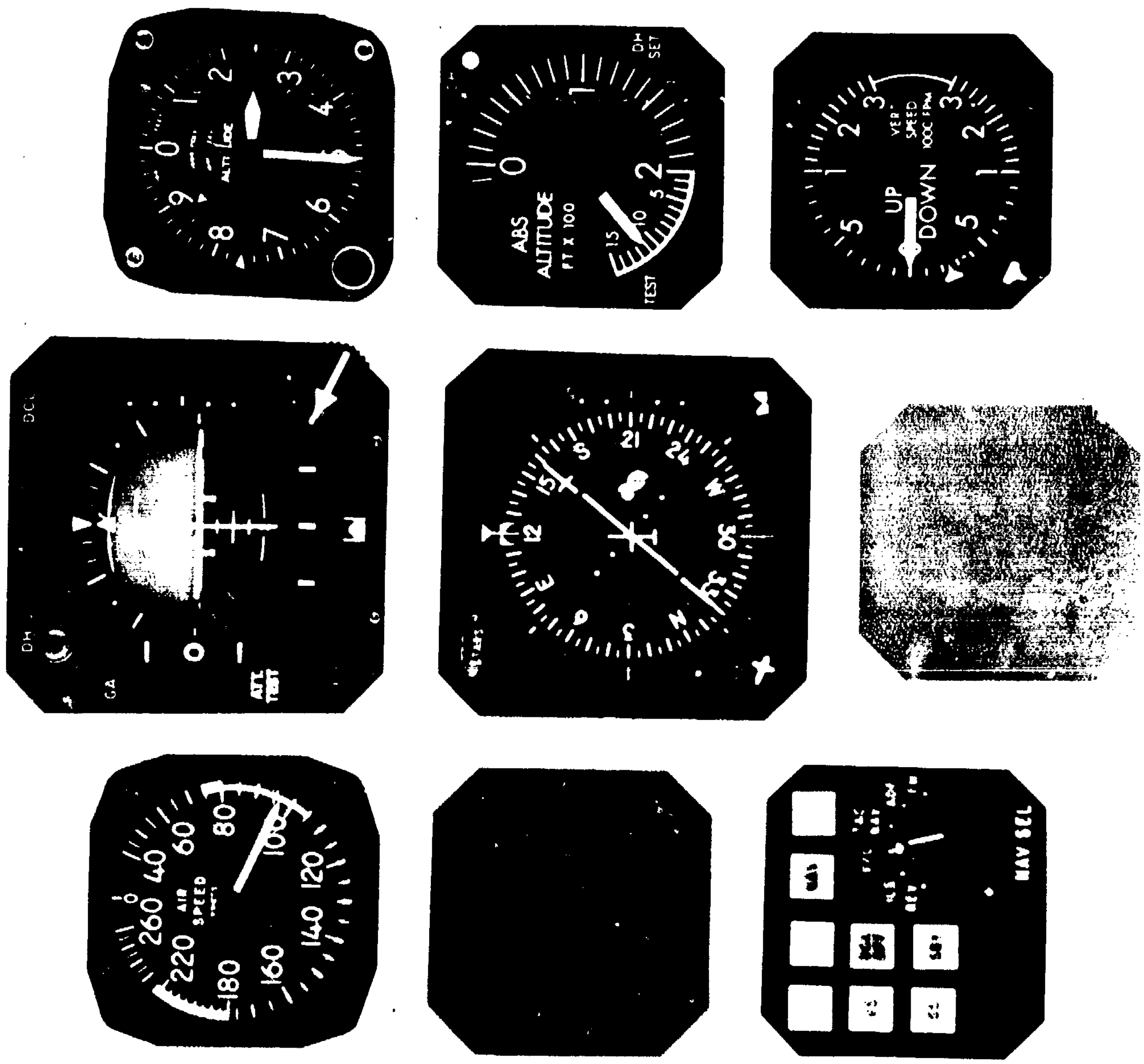


SLIDE 30.



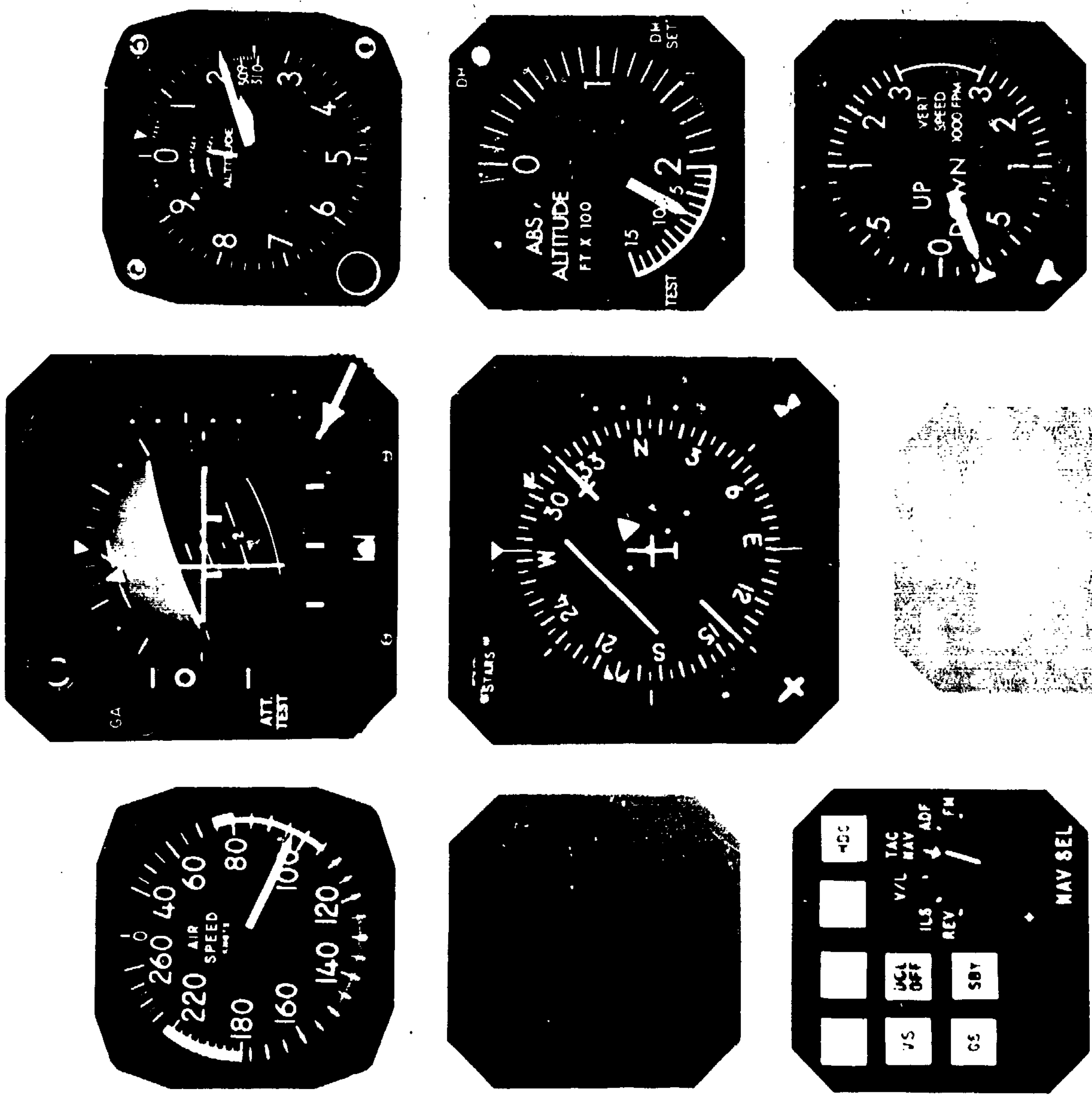

SLIDE 31.
ALT
ABS ALTITUDE FT X 100
OFF
WARNING LTS TEST

SLIDE 32.

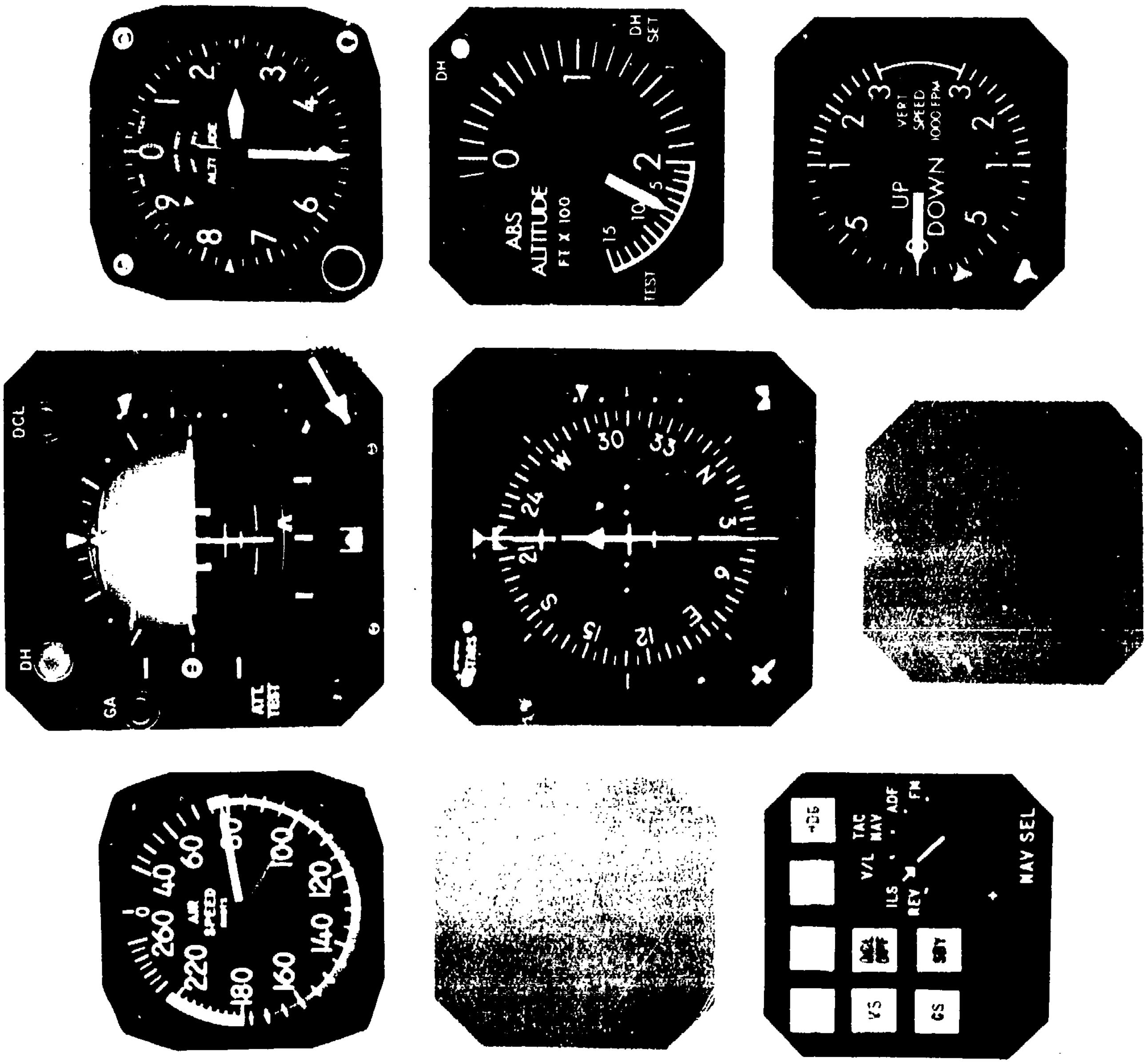


ABS
ALTITUDE
FT X 100
DH SET
TEST
VERT SPEED
UP
DOWN
AIR SPEED
ATT TEST
GA
DH
NAV SEL

SLIDE 33.

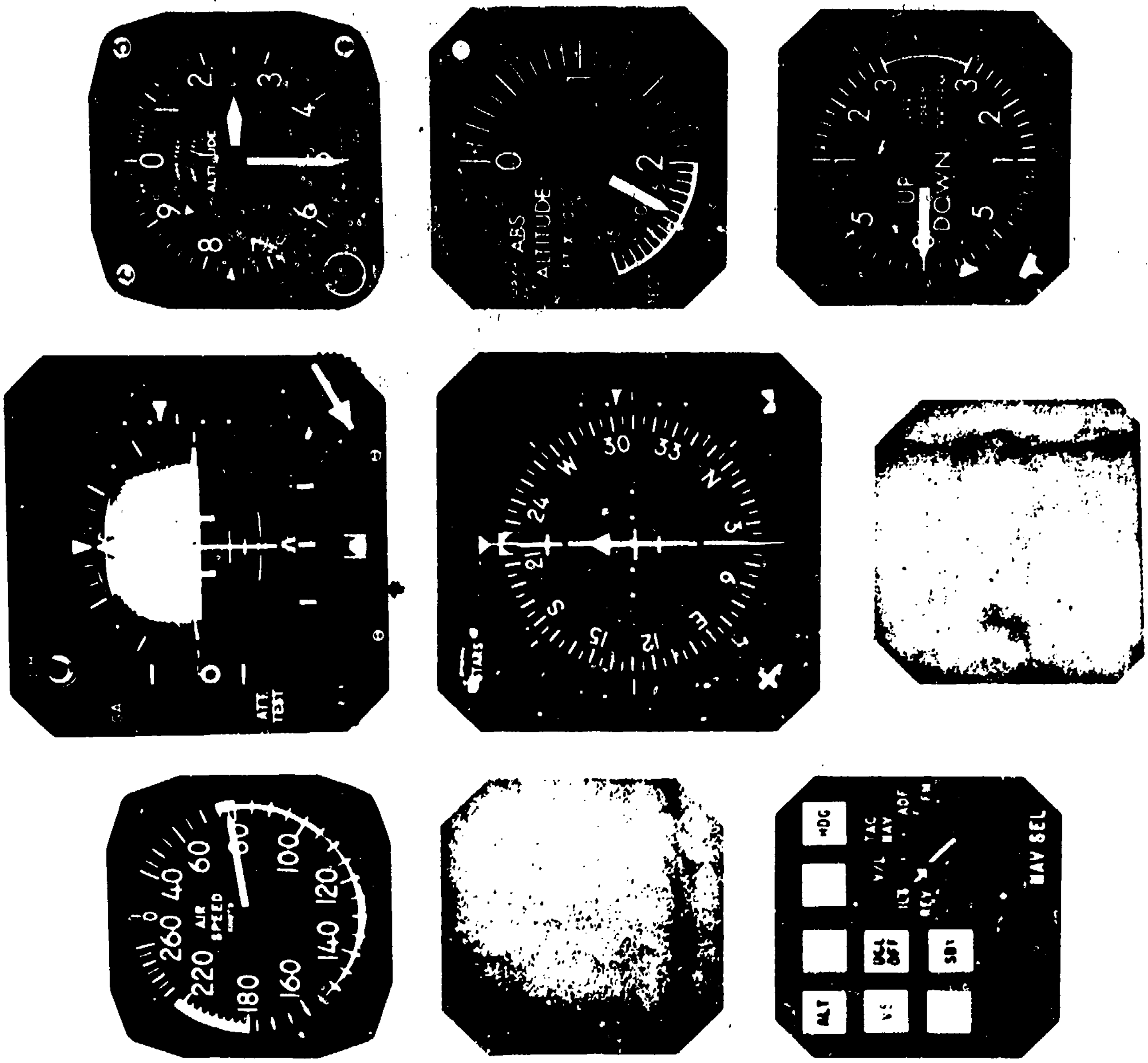

ALTITUDE
ABS. ALTITUDE
FT X 100
DH
DH SET
TEST
VERT SPEED 1000 FPM
UP
DOWN
ATT. TEST
GA
AIR SPEED
V/L
TAC NAV
ADF
ILS
REV
FM
NAV SEL

SLIDE 34

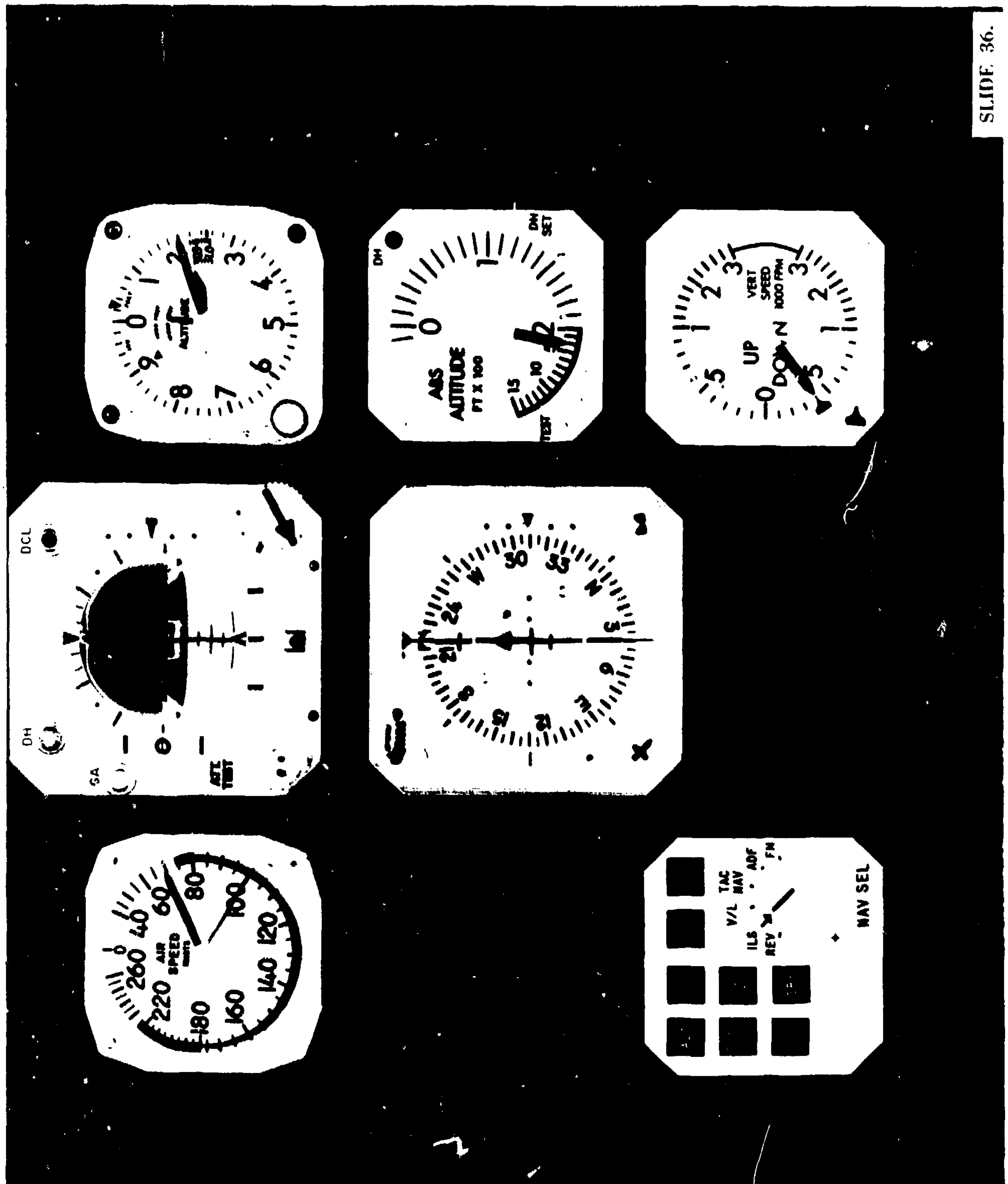


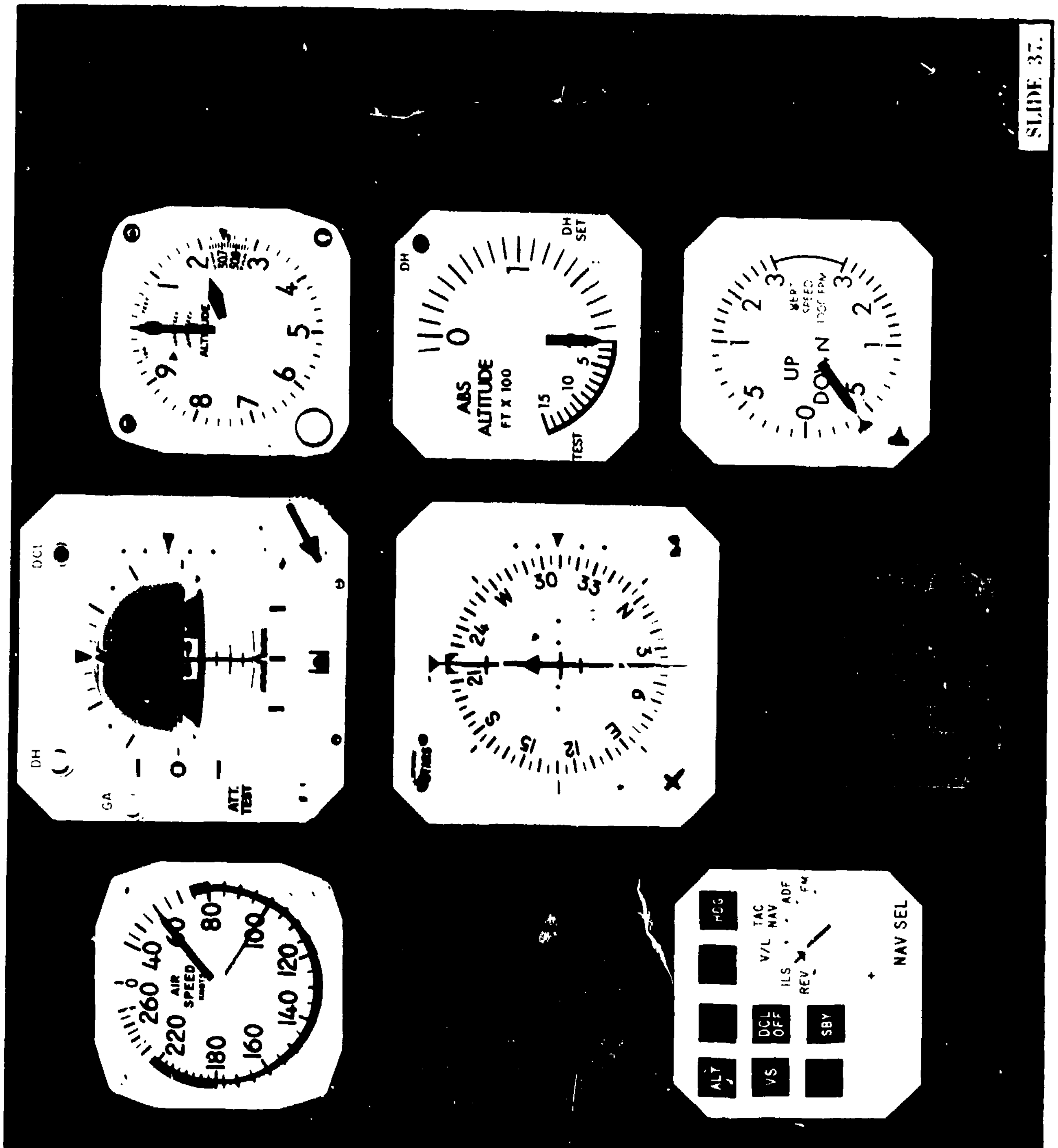
ABS
ALTITUDE
FT X 100
DH
DH SET
TEST
VERT
SPEED
1000 FPM
UP
DOWN
DCL
GA
ATT
TEST
AIR
SPEED
NAV SEL
TAC
NAV
ADF
V/L
ILS
REV
VS
GS

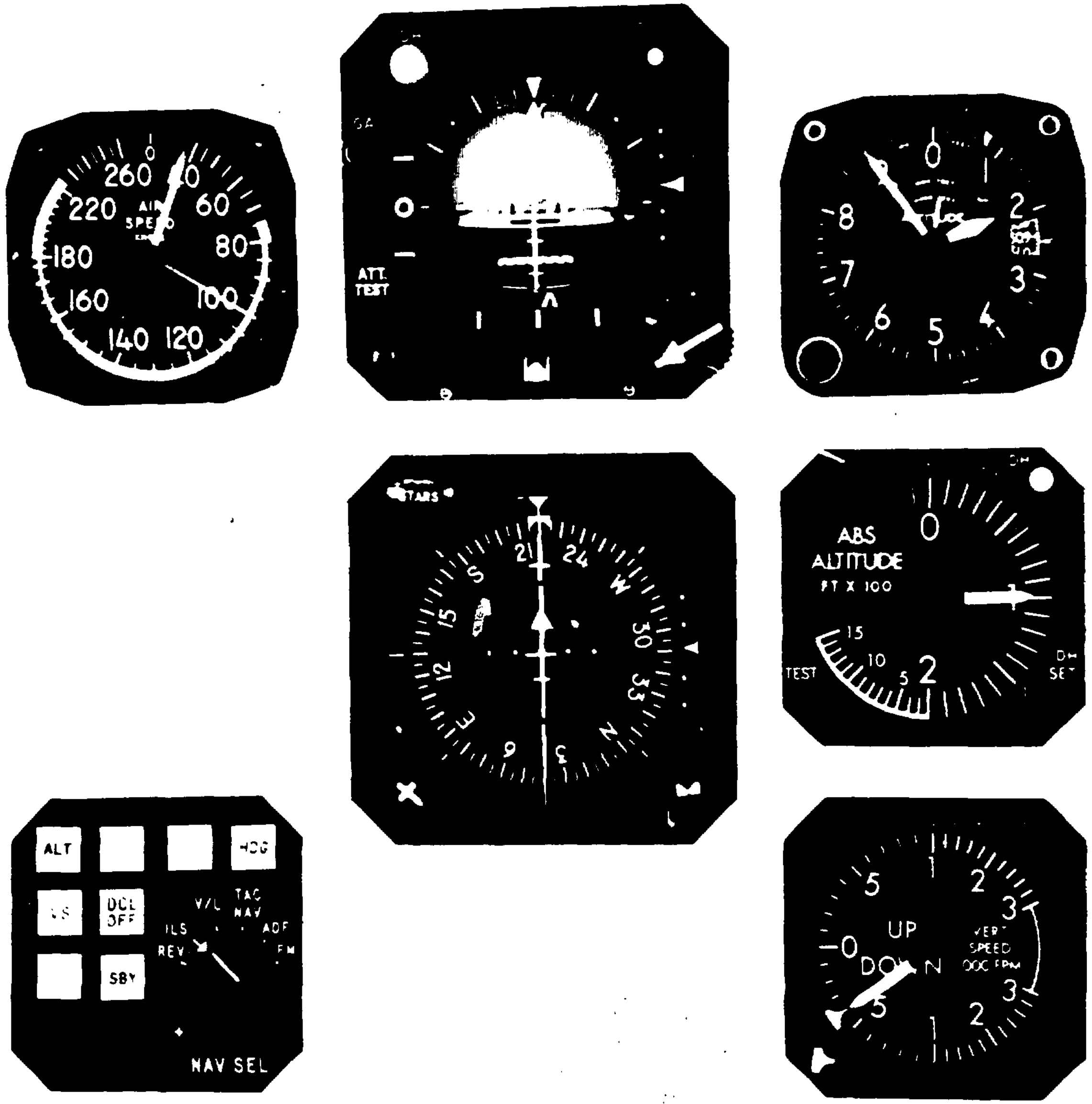
SLIDE 35.



ALTITUDE
ABS
ALTITUDE
UP
DOWN
ATT.
TEST
AIR
SPEED
NAV SEL
ALT
HDG


SLIDE 36.
AIR SPEED
ABS ALTITUDE
FT X 100
VERT SPEED
1000 FPM
UP
DOWN
DCL
DH
GA
NAV SEL
ILS
V/L
TAC NAV
ADF
REV


SLIDE 37.
AIR SPEED
ABS ALTITUDE
FT X 100
ATT. TEST
UP
DOWN
NAV SEL
HDG
ALT
VS
SBY
DCL OFF


AIR SPEED
ATT. TEST
ABS ALTITUDE FT X 100
TEST
DH SET
UP
DOWN
VERT SPEED 000 FPM
ALT
HDG
DCL OFF
SBY
V/L
TAC NAV
ILS
ADF
REV
FM
NAV SEL

SLIDE 38.

COL WRIGHT: Thank you, Major Smith.

We will now move to the other light observation helicopter, the OH-6. Major Warren Griffith graduated from the University of Wyoming in 1958, completed flight training in 1959, graduated from the Navy Test Pilot School in 1970. He came to the Activity in January 1972, participated at Sikorsky on the Attack Helicopter Evaluation and will discuss his testing with the OH-6.

OH-6A TESTING

MAJOR WARREN E. GRIFFITH II
EXPERIMENTAL TEST PILOT
US ARMY AVIATION SYSTEMS TEST ACTIVITY

Good morning, I am Major Griffith and I will discuss the OH-6 IFR evaluation. I will cover the results of the stability and control testing, operational performance and IFR evaluation of the basic OH-6 helicopter. I will then cover the preliminary results of the flight director evaluation. (The flight director system is now designated the helicopter command instrument system (HELCIS)) The remainder of my talk will cover the test procedures we use to conduct the IFR evaluation of the helicopter with a flight director installed, the evaluation of the flight director itself and then a brief description of the flight director system (FDS).

Next slide (slide 2)

The OH-6A helicopter is an all-metal, single-engine, rotary wing aircraft built by the Hughes Helicopter Company. The OH-6A design incorporates a single main lifting rotor and a tail rotor to provide antitorque and directional control. The helicopter is powered by an Allison T63-A-5A engine derated to a five-minute takeoff power of 252 shaft horsepower. The cockpit configuration is two-placed and has provisions for two passengers in the rear (cargo) area. Dual flight controls are provided and the control system is conventional and unboosted.

A flying qualities evaluation was conducted including the major tests shown on this slide.

Next slide (slide 3)

Those areas that are shown as discrepancies contained some unacceptable characteristics for IFR operations and will be discussed here. The remainder were considered acceptable and will not be discussed.

The first area I would like to discuss is control system characteristics. The flight control system is fully mechanical with no hydraulic boost and is provided with adjustable friction on the cyclic and collective controls. Since the friction forces were variable and not measurable, all adjustable friction was removed from the cyclic control. This then allowed usually unnoticed aerodynamic forces acting on the rotor system to be fed back to the pilot. The cyclic control is also equipped with an electromechanical trim system both longitudinally and laterally. However, with all control friction removed, there was a large band where the centering spring could not overcome the breakout forces of the system.

Next slide (slide 4)

This slide is a typical trace of longitudinal control forces with stick displacement from trim. The shaded area represents the normal stick displacement and resulting forces encountered in flight. The most significant point to note is the large trim control displacement band or the position band where stick forces are zero. This results in the pilot having no force cue for the true location of trim within this band and also produces very inadequate self-centering characteristics. Also it can be seen that up to 2 pounds of force are required to initiate cyclic movement either forward or aft from trim. The difference in the force gradients forward and aft of trim makes precise airspeed and altitude control very difficult. The lateral control system characteristics are satisfactory and will not be discussed here. The rotor system feedback showed up as random oscillations which were more dominant in the lateral than in the longitudinal axis and made precise control force measurements very difficult. The combination of inadequate self-centering and random rotor system feedback considerably degrades the cyclic position and force cues used by the pilot in attitude control when operating under IFR conditions.

Two other problem areas noted were in collective creep and directional control forces. Collective creep is undesired movement of the collective from its own weight or from reaction to rotor system feedback. To preclude collective creep, the collective friction must be high. The resulting high collective forces made small precise power adjustments extremely difficult. Directional control forces vary with power settings and airspeed, and are present throughout most of the flight envelope. The requirement to continually apply some pedal force increased the pilot effort necessary to maintain coordinated flight.

Another area of importance in handling qualities is the static stability of the aircraft. Static stability is basically a measure of the tendency of the aircraft to restore itself to a predetermined trim condition after some external disturbance. In the OH-6A the lateral-directional static stability was acceptable for IFR operations and so we will only discuss the longitudinal static stability.

Next slide (slide 5)

As mentioned by Mr. Lewis, the Mil Spec requires that both the stick position and stick force characteristics give evidence that the aircraft is statically stable. Under IFR conditions, the pilot also requires this, even if only subconsciously, to provide cues for airspeed and altitude control. As shown in this slide, the OH-6A possesses essentially neutral static longitudinal stability as evidenced by both control position and control force characteristics. From this data it can be shown that the helicopter can be stabilized at airspeeds ±15 knots from any trim speed above 60 knots with only about 0.1 inch of stick position change and no change in stick forces. Thus, if the pilot has to hold a constant airspeed during a flight task, for example, 80 knots during a timed tactical approach, any disturbance from that airspeed will result in the aircraft stabilizing at a new airspeed and requires the pilot to consciously fly the aircraft back to the desired airspeed. If his attention is diverted from the airspeed indicator, the pilot cannot maintain an airspeed due to the absence of cyclic position and force cues. These stability characteristics combined with the control system characteristics discussed earlier increase the pilot effort required for precise airspeed and altitude control to an unacceptable level. The long-term dynamic stability also enters into this problem and will be discussed next.

Next slide (slide 6)

You have already heard that the dynamic stability of a helicopter is a measure of the control-fixed natural oscillatory response to an out-of-trim condition. This slide attempts to portray the two dynamic responses of the aircraft. When excited, both of the blocks will move together vertically. This can be compared to the long-term response. It would also be noted that a much faster oscillation between the two blocks would also exist. This can be compared to the short-term response. In the helicopter these responses act in both the lateral-directional and in the longitudinal axes. Both the lateral-directional and the short-term longitudinal dynamic stability characteristics are acceptable for the OH-6A. However, the long-term longitudinal dynamic characteristics are not acceptable. A minute ago I said the dynamic characteristics and the static characteristics were interrelated and I will now attempt to describe this relationship. If the aircraft is disturbed from a trim condition, with controls fixed, static stability implies that the aircraft will return to the trim condition while dynamic stability implies that the aircraft will stop as trim is reached. Thus good dynamic stability damps out good static stability around trim and greatly assists the pilot in maintaining a preselected trim condition. In the OH-6A this longitudinal damping is so weak that any rate developed, either externally or with small control activities, will generally not damp out prior to an excessive deviation from the trim airspeed. The good short-term characteristics will stop the movement of the aircraft at some new pitch attitude. This new attitude will induce a change in airspeed but because of the essentially neutral static longitudinal stability characteristics, there is little or no tendency to return to the original trim airspeed. In addition, due to the very weak long-term dynamic characteristics, there is almost no tendency to arrest the change in airspeed until it has deviated excessively from the trim airspeed.

Next slide (slide 7)

These plots show the long-term characteristics. These are time histories of airspeed and are representative of the aircraft response to external disturbance. In this case (lower plot) a large disturbance results in the airspeed increasing to the maximum limit while you can see in this trace (upper) a very small disturbance results in a very slow and persistent oscillation in airspeed.

Now, I believe you can see that because of these characteristics the pilot must spend a disproportionate amount of time controlling airspeed and/or altitude to the detriment of his other duties such as navigating, communicating or making tactical decisions.

Next slide (slide 8)

This now concludes our discussion of handling qualities and I would briefly like to discuss operational performance. These are the various areas we looked at for operational performance. All of these areas were evaluated by numerous pilots, both test pilots and nontest pilots, with instrument proficiency levels ranging from very low to very high. Most of these evaluations were conducted during the mission profile flight that Mr. Lewis discussed earlier. The most significant problem area was noted in autorotational entry characteristics.

Next slide (slide 9)

This slide is a time history of a typical autorotational entry. The delay inherent in pilot recognition and response to an actual engine failure is simulated by delaying the collective application by 2 seconds. The thing I want to point out here is the large cyclic movement required following the power loss. During the entry phase, the cyclic is moved approximately 4.5 inches aft and 3.5 inches right just to maintain adequate control of the aircraft's attitude. You can see that even with this amount of cyclic movement, large pitch and roll rates still occur. This excessively large movement takes place in approximately 4-5 seconds and results in high pilot effort to maintain attitude during the autorotational entry. With the loss of external visual cues this is a very difficult maneuver to perform while maintaining controlled flight.

The remaining operational performance items are generally satisfactory, with the exception of some items noted in the cockpit evaluation. These items include an unsatisfactory attitude indicator and the lack of a vertical speed indicator and a turn needle. Also, additional navigation radios are necessary, the type depending on the theater of operations.

Next slide (slide 10)

This has covered in rather broad terms the IFR evaluation of the basic OH-6A helicopter. The general conclusions are that the basic OH-6A cannot be flown under IFR conditions without undue pilot effort and that it lacks adequate equipment to perform IFR flight.

In an effort to overcome these unacceptable areas, a Kaiser 3 cue FDS, Model FP 50, has been installed in the OH-6A. The flight director does not take the place of good handling qualities, but it greatly reduces the instrument scan pattern and allows the pilot to see flight path errors much more quickly. Two evaluations are in progress at this time, one to determine the effect on pilot workload and flight path accuracy by the addition of an FDS and the other a comprehensive evaluation of the FDS itself.

Next slide (slide 11)

The objectives of these evaluations are:

1. Determine flight control activity and flight path accuracy for various mission segments using the FDS.

2. Determine if the FDS will minimize absolute altitude deviations and reduce pilot workload with respect to the OH-6A longitudinal stability.

3. Determine the limits to which the aircraft can be flown using the FDS commands under comparable VFR and IFR conditions.

4. Determine the lowest limit to which each FDS command can be followed.

5. Determine the maximum steep approach angle practical for VFR and IFR with and without FDS.

6. For each flight mode determine which FDS command provides the most assistance in reducing pilot workload and improving flight path accuracy.

7. Determine the minimum altitude for suppressing the FDS commands.

8. Establish a safe missed-approach transition to a climb-out with respect to FDS airspeed and vertical speed commands.

9. Determine what modes are desired for the entire flight regime.

Next slide (slide 12)

All control activity and flight path parameters are recorded on the airborne tape recording system shown in this slide. We record 20 channels of data. These data are then run through a computer which conducts a complete control activity and flight path accuracy analysis.

Next slide (slide 13)

This slide shows a list of the major items of data output from our computer program. As Mr. Lewis stated earlier, we are not exactly sure which parameters provide the most accurate measure of pilot workload so we have performed all of these analyses so that we can evaluate different methods of workload determination. I believe items 1, 2 and 3 are self-explanatory. Item 4, control movement density analysis, is a measure of frequency of control position occurance in 1-percent increments of total control throw, measured from the mean. I will clarify this in a minute. Items 5, 6 and 7 are the results of statistical analysis conducted on half-cycles of control activity as measured above and below the mean. Items 1, 2, and 3 will also be determined for flight path analysis.

Next slide (slide 14)

With this next slide we can quickly walk through the most important parts of the data analysis. The analysis of this control trace is conducted on 60 seconds of a 2-minute data recording. This 1-minute slice is sampled at a rate of 25 points per second. The analysis then performed determines the mean and standard deviation which then becomes our reference conditions. Following that, the density analysis is performed. This is a summation of the data points falling in each 1-percent band. That is 1 percent of total control throw. Next the half-cycle area analysis is performed.

Next slide (slide 15)

This slide defines the four flight modes which are used to obtain workload and flight path accuracy data. The basic VFR mode is used as a base line to which the other three modes are compared. These are the five pilot tasks that are evaluated. Each of the five tasks are evaluated in all four flight modes. For each pilot task, applicable parameters such as airspeed, rate of climb, and descent angle are varied to determine their effect on workload and flight path accuracy. From this, the flight parameters which produce the minimum pilot workload for each task will be determined. These tests will provide the data necessary for the FDS evaluation and the evaluation of the OH-6A with an FDS installed.

Next slide (slide 16)

This is some initial data which I believe shows the basic trends in flight path accuracy and pilot workload. It can be seen that generally, flight path error increases under instrument flight conditions as shown by standard deviation in this table. The one exception is the decrease in airspeed error with the addition of the FDS. The addition of the FDS assists greatly in reducing flight path error. The pilot workload comparison corresponds to the flight path accuracy comparison shown above. We have presented three methods of determining workload. The three general columns taken by themselves show three different results and thus cannot be used independently. Comparing control area with half-cycle count it can be seen that, when going to IFR, control activity and deflective increase and with the addition of the FDS, control activity increases even further but as shown in the control area column, stick deflection is greatly reduced which results in the reduction of control area. In all cases standard deviations remain essentially the same. These trends do agree with qualitative pilot opinion in that there is an apparent increase in workload IFR with respect to VFR with a reduction when the FDS is added, but not to the original level noted for VFR.

Next slide (slide 17)

I have been referring to the Kaiser 3 cue FDS for the past few minutes and I would now like to finish up with a brief description of the system and an explanation of how it works. This is a view of the instrument panel of the OH-6A with the flight director installed. This panel (left) is the standard OH-6A instrument panel. The flight director panel has been added here (right) and contains the flight director indicator, horizontal situation indicator, radio magnetic indicator, vertical speed indicator, barometric altimeter, radar altimeter and turn and slip indicator.

Next slide (slide 18)

The flight director indicator incorporates a cathode ray tube display, as shown in this slide. All the controls for the system are located on the front of the flight director indicator. On the left is the horizontal mode selector. This switch selects the sensors and method of computation appropriate for the type of lateral cyclic steering commands desired. In the heading (HDG) position intercept and tracking information is displayed for the selected magnetic heading. In the FM position, information is presented to home on an FM station. In ADF, VOR and LOC localizer positions, intercept and tracking information is presented. The vertical (VERT) switch on the right selects the sensors and method of computation appropriate for the type of longitudinal cyclic and collective commands required. In the AH mode, the system provides the pilot information necessary to hold the barometric altitude at which the aircraft is flying when the mode was selected and a constant airspeed. The GS mode provides the pilot information necessary to track the ILS glide slope beam and to hold a constant airspeed. The NORM position provides the pilot information to perform a descent which is currently set up at 80 knots and approximately 600 feet per minute (FPM) which roughly corresponds to a 5-degree descent angle. The STEEP position commands a 60-knot and 900FPM descent which roughly corresponds to a 10-degree descent angle. All rates of descent down to 300 feet radar altitude are generated as a function of barometric altitude change. Incorporated in the glide slope, normal and steep modes are deceleration modes which automatically engage at 300 feet radar altitude and are programmed to cause the pilot to decelerate the aircraft to stabilize at 40 knots and 50 feet absolute. The hover (HVR) position is for follow-on equipment which will direct the pilot to lower airspeeds and altitudes at the termination of an approach. A go-around mode is incorporated for all descent modes which, when activated, directs the pilot to establish a 500-FPM, 80-knot climb while maintaining the heading information based on the horizontal mode previously selected.

The symbols shown are the command symbols. This square is the collective command. Its vertical position relative to the horizon provides commanded collective position information. The position of the apex of this triangle relative to the horizon indicates a command to move the cyclic stick. Lateral movement of the apex relative to the center of the horizon, indicated by this small white square, indicates a lateral cyclic movement or steering command. Vertical motion indicates a longitudinal cyclic movement or airspeed command. The symbology here shows that the aircraft is on airspeed, on altitude, but requires a right turn to intercept a VOR radial.

This short film shows the flight command movement during a turn to a preselected heading while holding altitude and airspeed, followed by the entry into a steep approach.

FILM

As I stated earlier, a flight director cannot replace undesirable handling qualities; however, the 3 cue system does allow for better utilization of the unique capabilities of the helicopter.

Gentlemen, this completes my portion of the briefing.

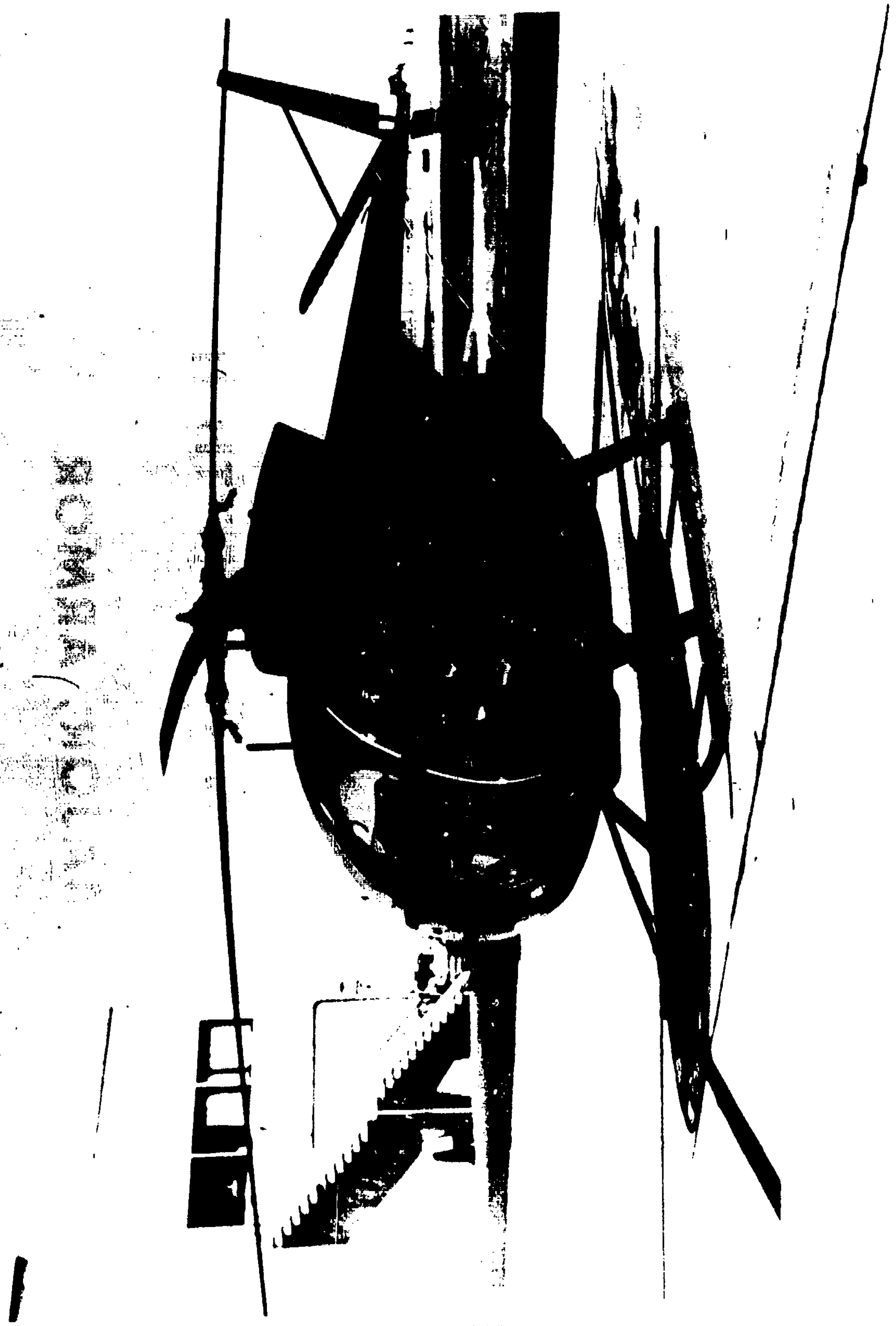
OH-6A

IFR EVALUATION

WARREN E. GRIFFITH II

MAJOR, ARMOR

SLIDE 1.



SLIDE 2.

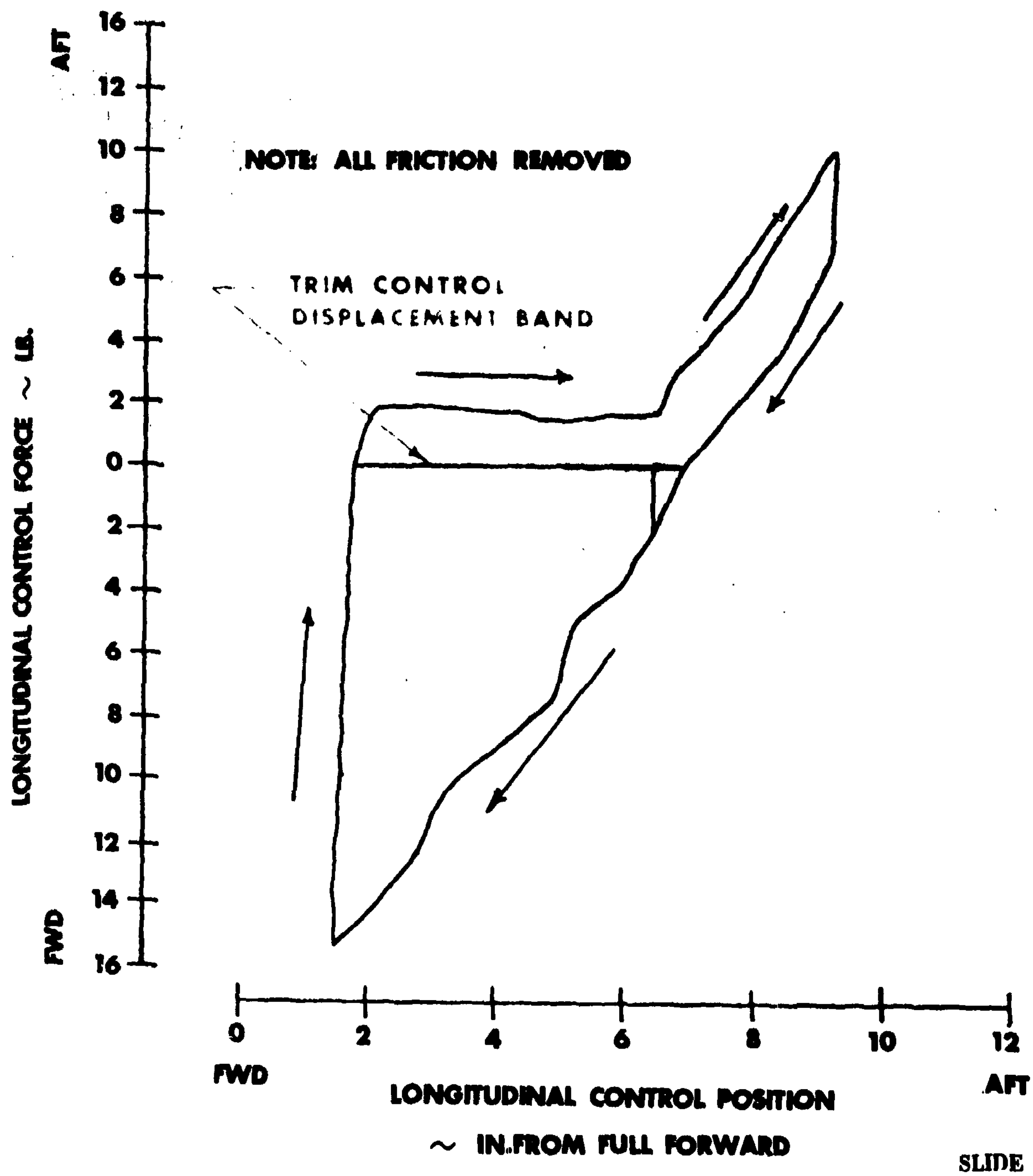
OH-6A
MAJOR TEST AREAS

DISCREPANCIES	SATISFACTORY	TEST
X		CONTROL SYSTEM CHARACTERISTICS
	X	CONTROLLABILITY
	X	CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
X		STATIC LONGITUDINAL STABILITY
	X	STATIC LATERAL-DIRECTIONAL STABILITY
X		DYNAMIC LONGITUDINAL STABILITY
	X	DYNAMIC LATERAL-DIRECTIONAL STABILITY
X		IFR AUTOROTATIONAL ENTRY CHARACTERISTICS
X		COCKPIT EVAUATION
X		PILOT WORKLOAD/FLIGHT PATH ACCURACY

SLIDE 3.

CONTROL SYSTEM CHARACTERISTICS

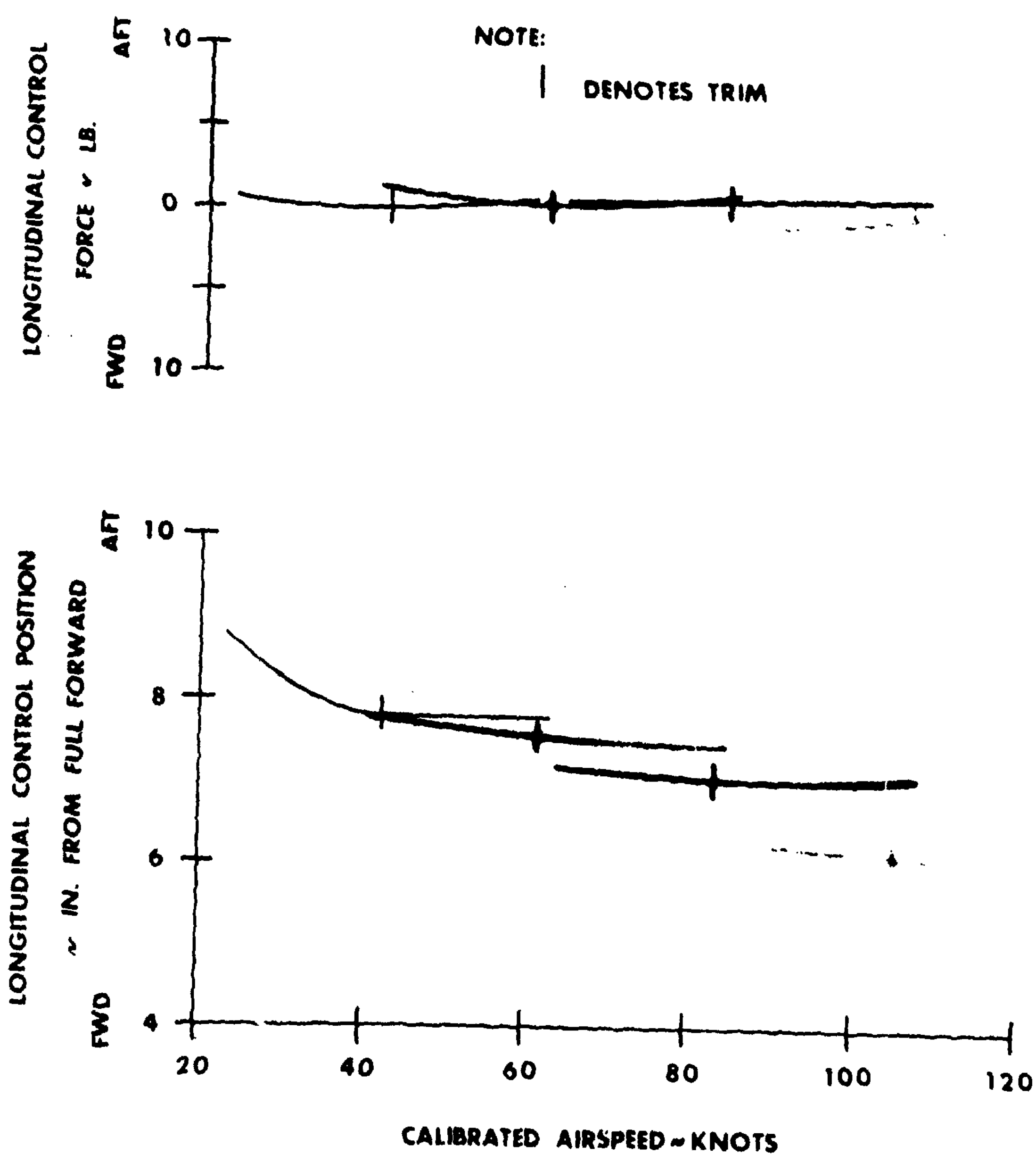
OH-6A



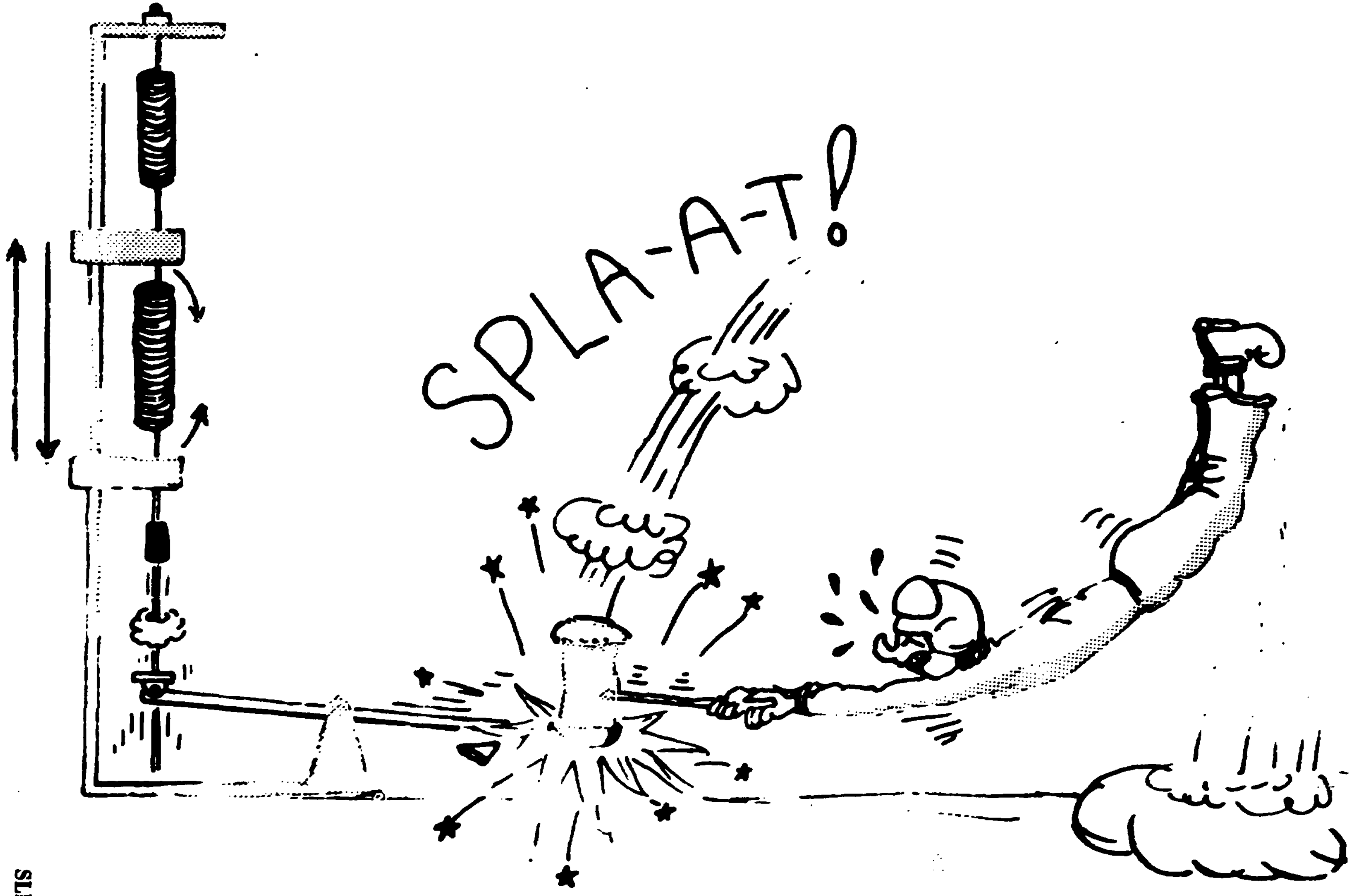
SLIDE 4.

STATIC LONGITUDINAL STABILITY

OH-6A



SLIDE 5.

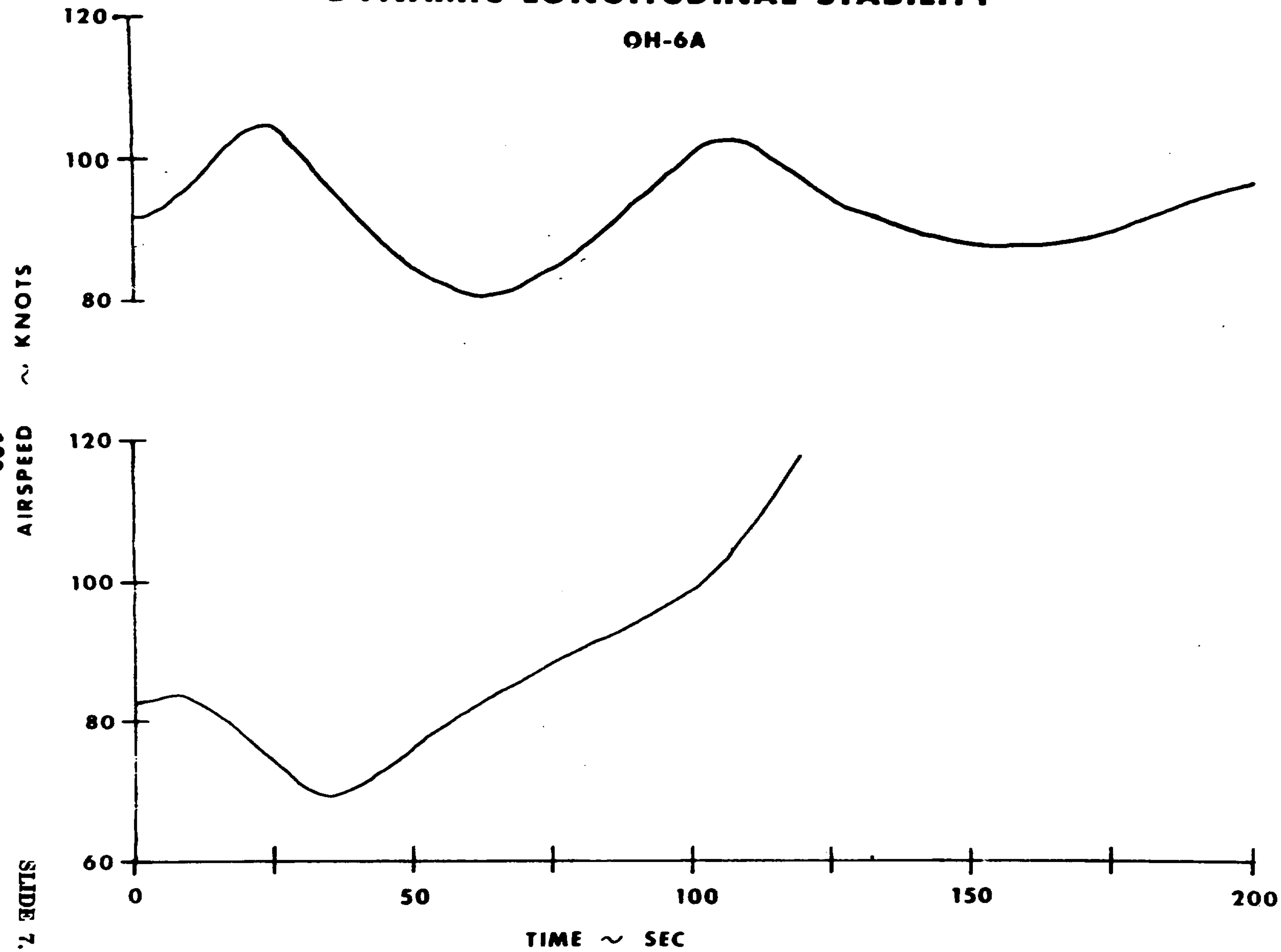


DYNAMIC LONGITUDINAL STABILITY

SLIDE 6.

DYNAMIC LONGITUDINAL STABILITY

OH-6A



SLIDE 7.

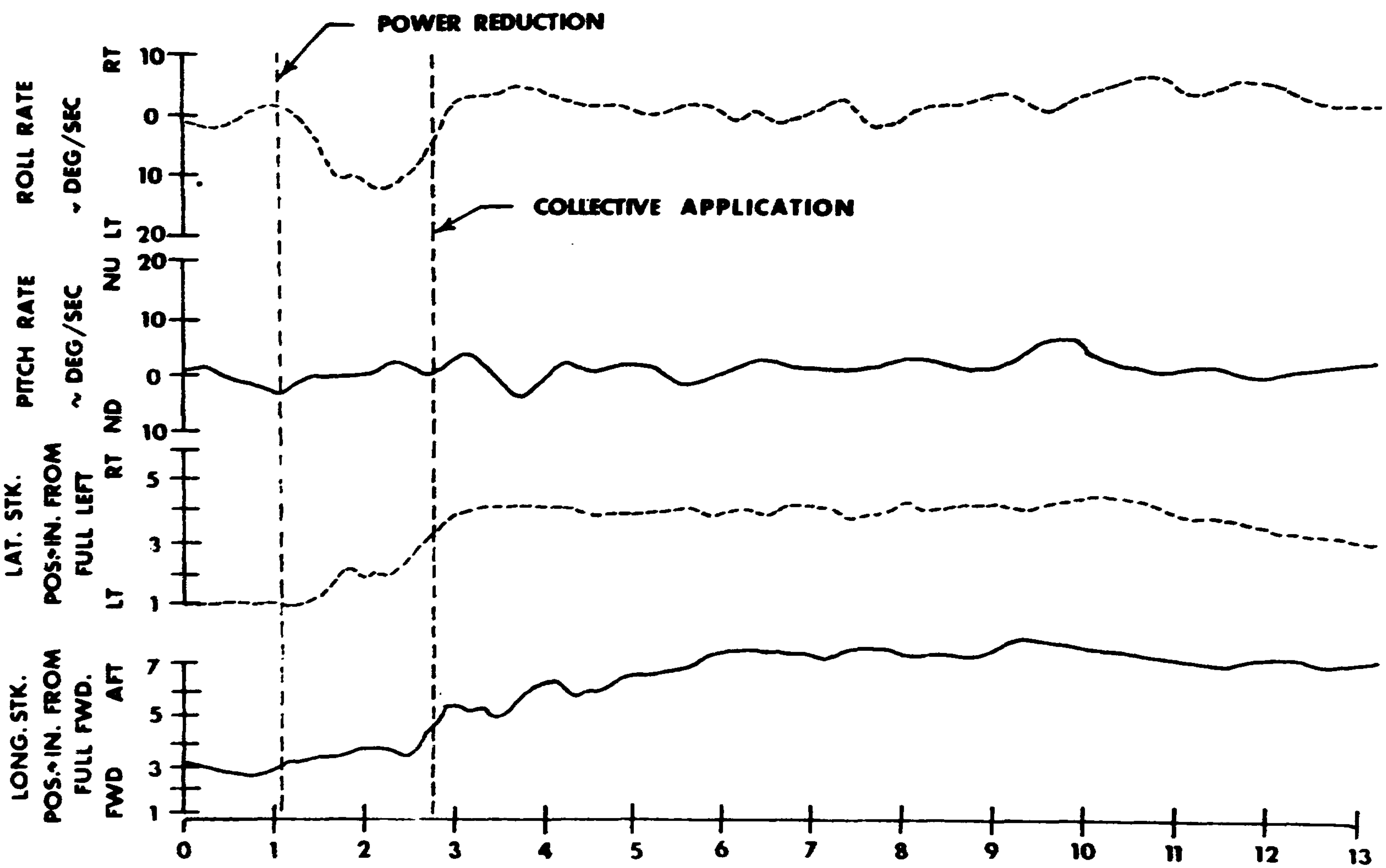
OPERATIONAL PERFORMANCE

- AUTORATIONAL ENTRY CHARACTERISTICS, SIMULATED IFR
- UNUSUAL ATTITUDE RECOVERY CHARACTERISTICS
- NIGHT INSTRUMENT-FLIGHT CHARACTERISTICS
- PARTIAL-PANEL CHARACTERISTICS
- INSTRUMENT-FLIGHT AIRSPEEDS
- INSTRUMENT-FLIGHT MISSION PROFILE
- COCKPIT EVALUATION

SLIDE 8.

AUTOROTATIONAL ENTRY

OH-6A



SLIDE 9.

GENERAL CONCLUSIONS

BASIC OH-6A

1. CANNOT BE FLOWN UNDER IFR CONDITIONS WITHOUT UNDUE PILOT EFFORT

2. LACKS ADEQUATE EQUIPMENT TO PERFORM IFR FLIGHT

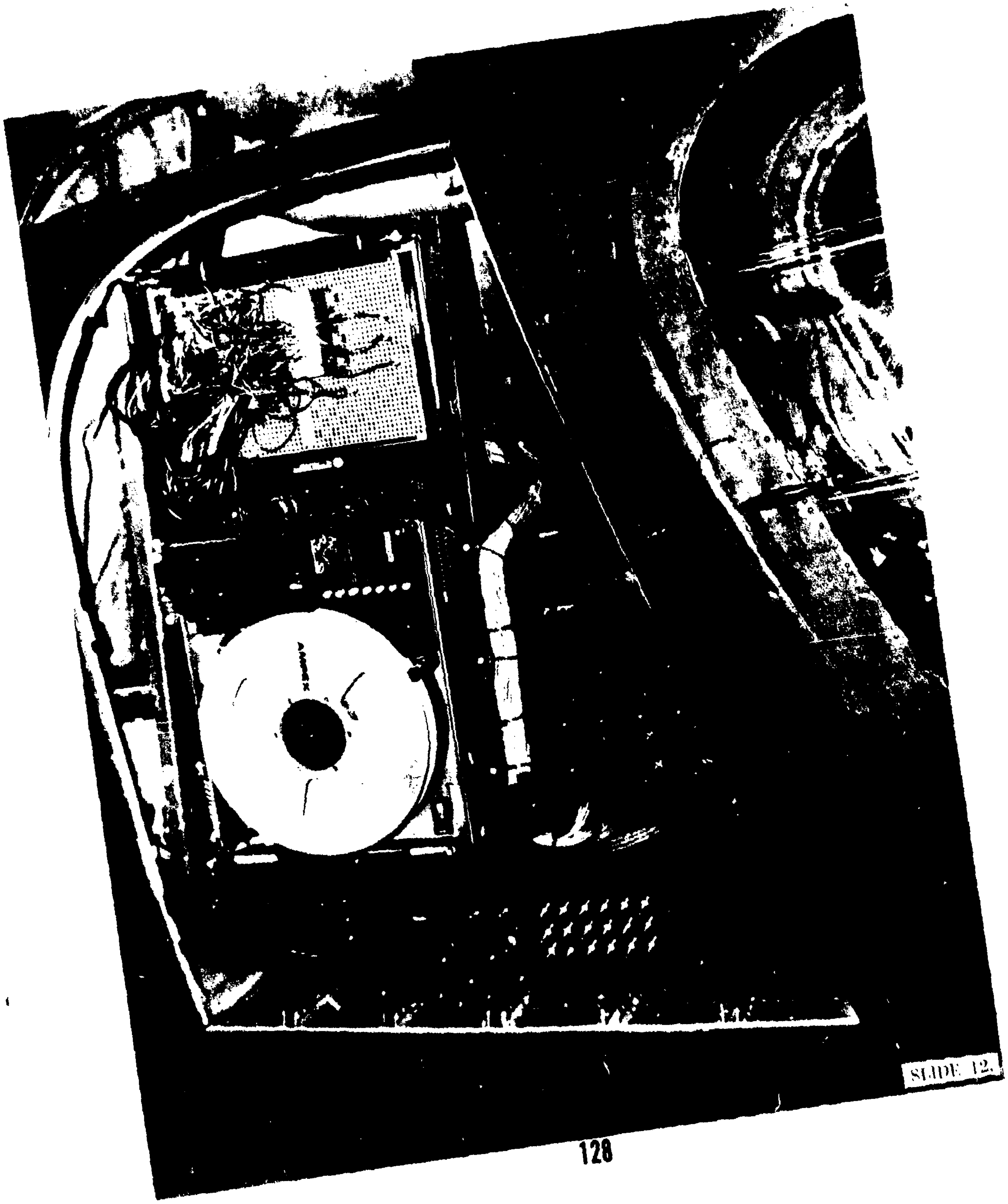
SLIDE 10.

OH-6A FLIGHT DIRECTOR SYSTEM IFR EVALUATION

TEST OBJECTIVES

- CONTROL ACTIVITY AND FLIGHT PATH ACCURACY
- STATIC LONGITUDINAL STABILITY
- AIRCRAFT LIMITS
- COMMAND LIMITS
- AIRCRAFT APPROACH LIMITS
- FLIGHT MODE / COMMAND
- MINIMUM ALTITUDE
- MISSED APPROACH
- FLIGHT MODE EVALUATION

SLIDE 11.



SLIDE 12.

IFR EVALUATION PROGRAM ANALYSIS

1 MEAN

2 STANDARD DEVIATION ABOUT MEAN

3 MAXIMUM-MINIMUM

4 CONTROL MOVEMENT DENSITY ANALYSIS

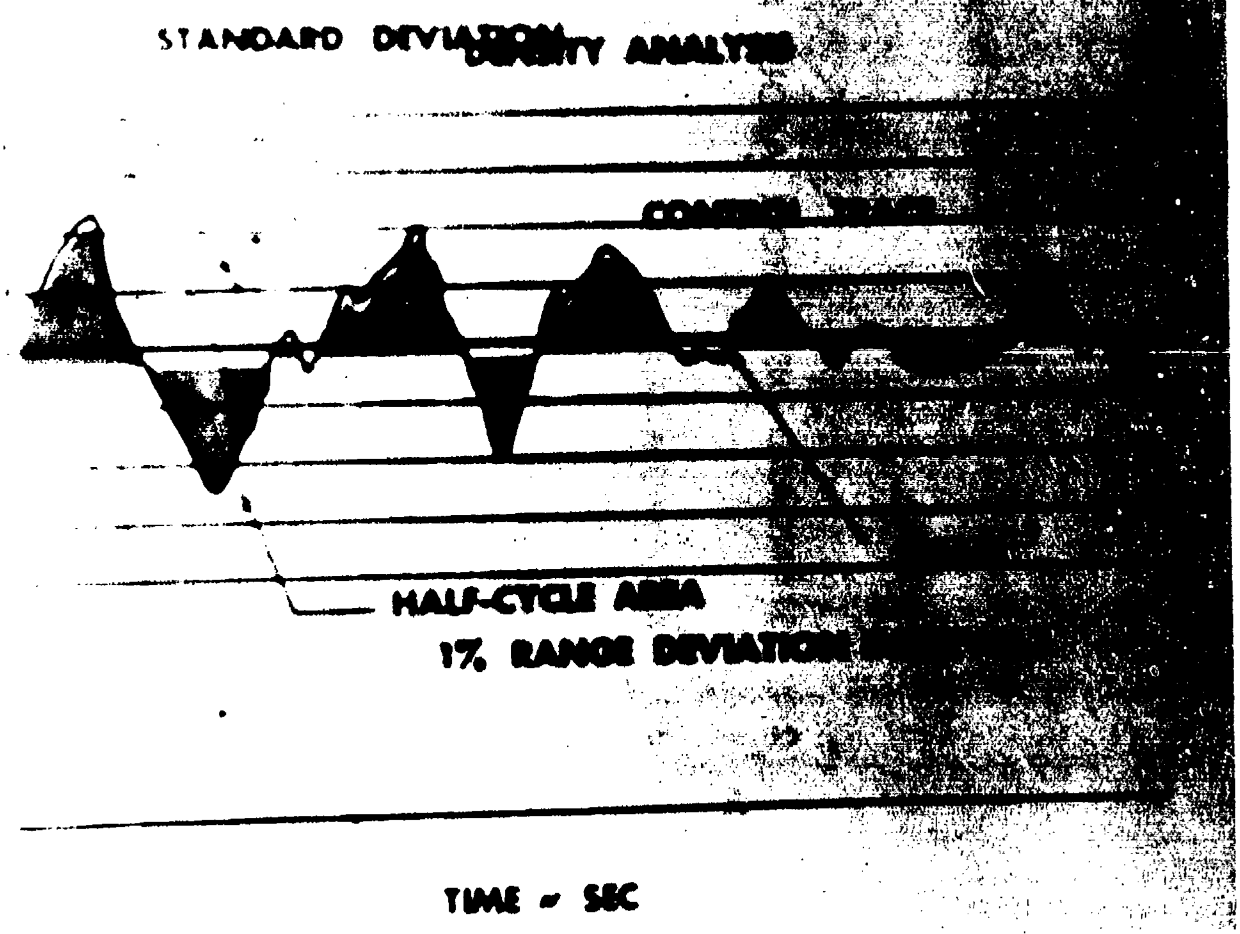
5 HALF-CYCLE FLUCTUATION ANALYSIS

6 HALF-CYCLE AREA ABOVE AND BELOW MEAN

7 HALF CYCLE DENSITY ANALYSIS

SLIDE 13.

CONTROL ANALYSIS



SLIDE 14.

FLIGHT MODES

- **VFR**
  VISUAL FLIGHT USING EITHER OUTSIDE REFERENCES OR STANDARD OH-6 COCKPIT INSTRUMENTS.
- **VFR/FDS**
  VISUAL FLIGHT USING FDS AS DESIRED BY THE PILOT.
- **IFR**
  INSTRUMENT FLIGHT USING ALL STANDARD OH-6A COCKPIT INSTRUMENTS.
- **IFR/FDS**
  INSTRUMENT FLIGHT FOLLOWING THE FDS COMMANDS.

PILOT TASKS

- **CLIMB**
- **CRUISE**
- **DESCENT**
- **HOLDING PATTERN**
- **IFR APPROACH**

SLIDE 15.

FLIGHT ACCURACY COMPARISON

OH-6A

FLIGHT MODES	AIRSPEED ERROR (KT) (1)	ALTITUDE ERROR (FT) (2)	HEADING ERROR (DEG) (3)
VFR	0.9	9	1.4
IFR	1.7	20	2.1
IFR/FDS	0.4	9	1.9

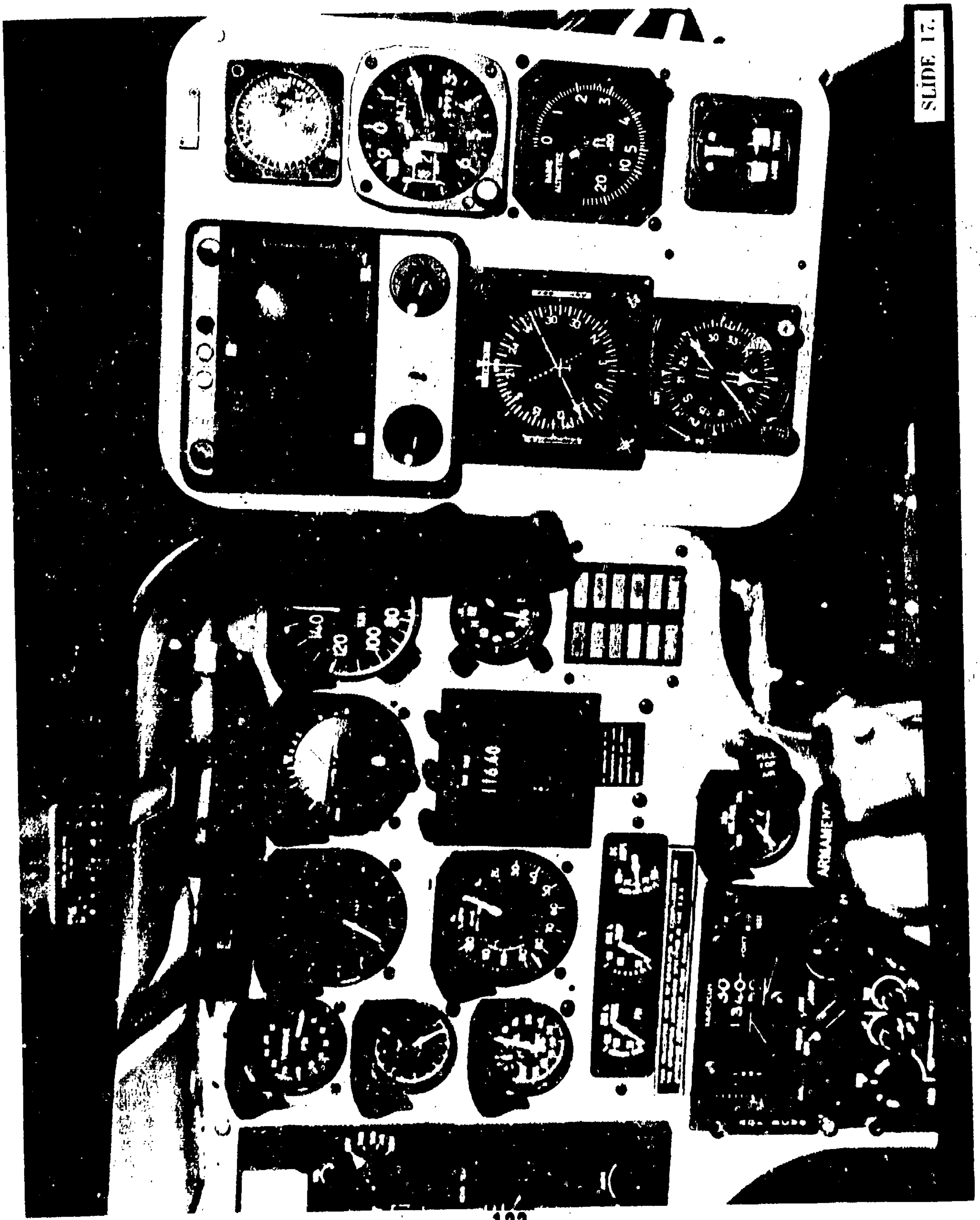
(1) STANDARD DEVIATION FROM MEAN AIRSPEED
(2) STANDARD DEVIATION FROM MEAN ALTITUDE
(3) STANDARD DEVIATION FROM MEAN HEADING

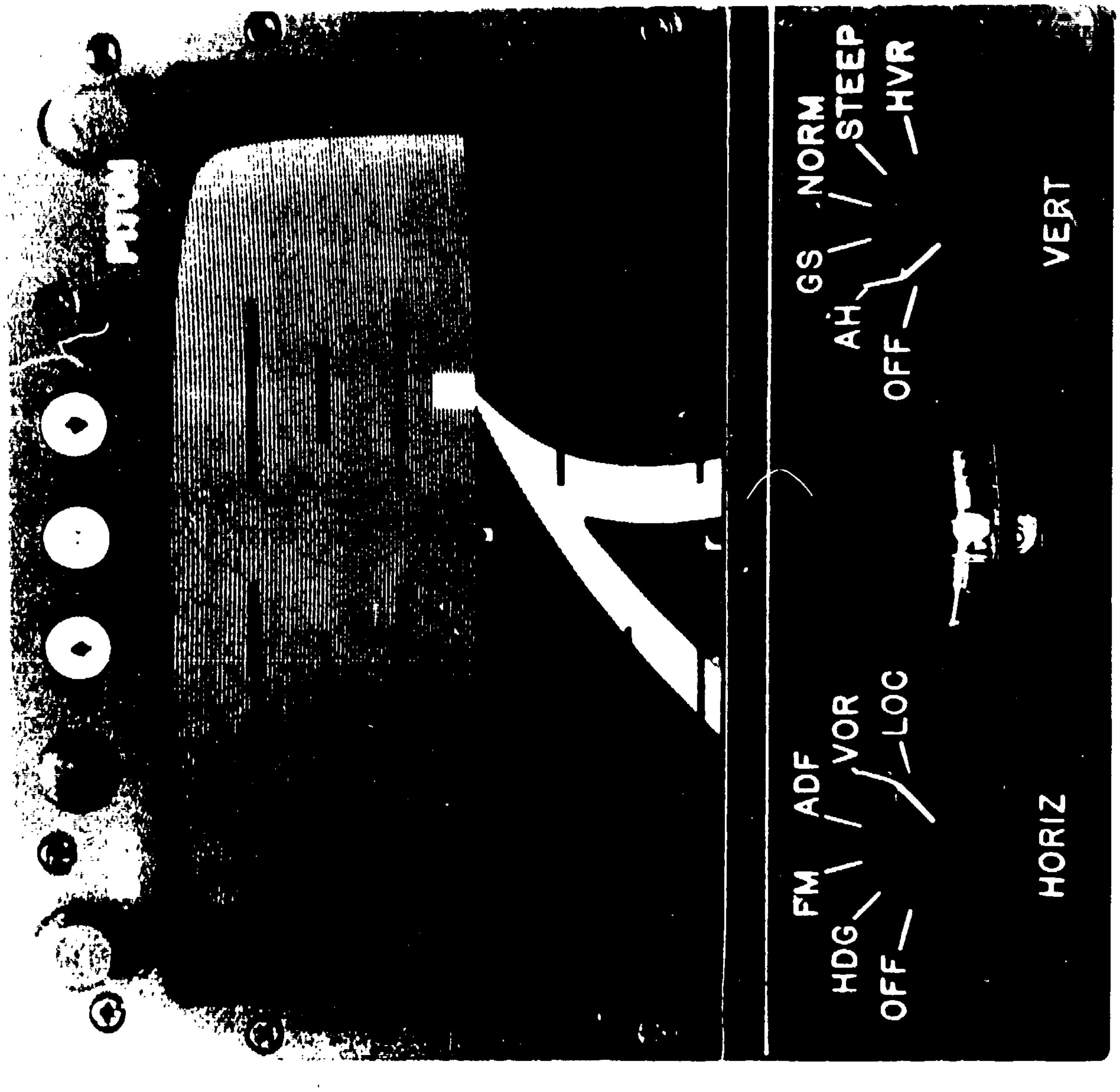
PILOT WORKLOAD COMPARISON

CONTROL POSITION ANALYSIS

FLIGHT MODE	CONTROL AREA (IN.-SEC)		STANDARD DEVIATION (IN.)		HALF-CYCLE COUNT	
	LONG.	LAT.	LONG.	LAT.	LONG.	LAT.
VFR	3.32	7.10	0.11	0.12	29	47
IFR	9.38	10.25	0.11	0.12	32	68
IFR/FDS	5.75	8.16	0.07	0.10	37	[illegible]

SLIDE 16.


SLIDE 17.
ARMAMENT



SLIDE 18.

DISCUSSION AFTER MAJOR GRIFFITH'S SPEECH

MR. HENSCHEL, Bell Helicopter: During Major Smith's briefing on the OH-58, he felt that the SCAS had a much greater effect on pilot workload. Can we plan on SCAS or other stabilization and would you comment on what effect that might have on the pilot workload?

COL WRIGHT: To my knowledge there is no plan for SCAS in the OH-6. We've not been asked to evaluate that.

MR. MCMANUS, AVSCOM: You are going to get a SCAS on the OH-6.

COL WRIGHT: I stand corrected. We haven't received a test directive to evaluate it yet, but as of now we have a test directive to evaluate a SCAS on the OH-6. Any additional questions?

MR. HENSCHEL, Bell Helicopter: I wonder if I can get a comment in regard to the visual situation display as opposed to an indicator, *ie*, the CRT display as opposed to a standard one, from Major Griffith or Major Smith.

MAJ GRIFFITH: Well, maybe I could start with one thing; both of us have flown both systems and I feel that both displays have their merit. We are really not here to make any comparisons and I can't compare. But the one thing I did not bring out for the cathode ray display, a problem that must be addressed, is the impact light coming into the cockpit from outside has on the tube itself. This has been addressed and one thing that you might have noticed was a funny look to that tube. It has a screen over it which directs light and blocks light from striking the face of the scope, but it also must be realized that this, right now, is being looked at for IFR flight, which means restricted visibility – probably no bright sunlight. If the direct sunlight is not on the scope, it is not – just – high ambient light is no problem – it's direct sunlight. Now, that is what I would say about cathode ray tubes and duck the rest of it.

COL WRIGHT: Major Smith.

MAJ SMITH: Our mission here was not to compare the two. Just looking at the merits of both of them. When we talked about the Sperry earlier, I tried to highlight the good features as well as some of the bad, because both systems, as I see it, have advantages and disadvantages. I don't think we are in a position to say which is the way to go – instruments versus cathode ray.

QUESTION FROM ATTENDEE: One further question in this line. The relationship of the ASTA presentation to the pilot. I'm sure that if you had your druthers, you would prefer them located directly on the pilot's centerline as opposed to slightly off. In regards to an observation aircraft, I remember the CRT display was slightly over on your centerline and you comment you got some parallax - it was slightly off. Just give me a little indication - is it out of the question to keep the instrument panel on the small side, therefore, maybe necessitating instruments slightly off-center; or in really considering basic design from IFR standpoint, is it paramount? That is, instruments on the pilot's centerline.

MAJ SMITH: I think the small panel is the only answer to our problem in the case of these two aircraft - they're Scout aircraft primarily - instrument flight, I think, is kind of secondary. If you have got a large panel there, then you can't see what you are doing so you need a small panel. These are both test aircraft. The parallax situation of the OH-58 could be eliminated by simply canting the instruments so the pilot can see it directly straight ahead or it could be tuned internally, so that he sees a slightly offset needle. There are many approaches to it that I feel we could take. I don't think a large panel is the answer, personally.

MAJ GRIFFITH: On the OH-6, the added panel was placed because the basic instrument panel is all one piece - console and the whole thing is one piece. It was not feasible in the time constraints that we had to reconstruct the entire instrument grouping. That panel was added as a very rapid solution to the problem and also, I might point out, there is no parallax involved with a cathode ray since it's all presented on a flat surface and centerline orientation is not that important. I believe the other considerations - you get the same characteristics and still have the VFR capability with them.

COL WRIGHT: This afternoon we are going to move on to the CH-54 and AH-1G. To present the results of our CH-54 evaluation I'm calling on Mr. Joe Watts. Mr. Watts graduated from Florida A&M University in 1954, with a BS in math and physics. He received his wings in 1955, graduated from the Air Force Test Pilot School in 1960, and came to the Activity in 1965. I guess Joe has flown about everything the Army has ever tested. This afternoon he will discuss his testing with the CH-54.

CH-54B IFR EVALUATION

JOSEPH C. WATTS
EXPERIMENTAL TEST PILOT
US ARMY AVIATION SYSTEMS TEST ACTIVITY

First slide

During the previous two presentations we have been focusing attention on two of the smaller helicopters in the inventory, light observation type, of fairly simple design. For the next few minutes we will focus attention on the largest helicopter in the inventory, heavy lift, cargo type, of fairly complex design.

Next slide (slide 2)

The CH-54B helicopter is a large, single-rotor, crane-type helicopter manufactured by Sikorsky Aircraft Division of United Aircraft Corporation. The CH-54B design incorporates a single main lifting rotor and a tail rotor for antitorque and directional control. The main rotor is a six-bladed, fully articulated system and the tail rotor is a four-bladed, semiarticulated system. Power for the CH-54B is furnished by two Pratt and Whitney Model T73-P-700 gas turbine engines rated at 4800 shaft horsepower each under sea-level, standard-day conditions. The helicopter has a fixed-tricycle landing gear with a full swiveling nose wheel and dual main wheels.

Actually, the IFR tests on the CH-54B preceded the tests discussed during the previous presentations. Because of the calendar time constraints, the CH-54B tests were principally oriented toward the stability and control requirements of MIL-H-8501A. The adequacy of the avionics equipment in the CH-54B for accomplishing enroute navigation and instrument approaches was qualitatively assessed. Tests were conducted at a hover (IGE), in level flight, climb and autorotation at gross weights ranging from 30,000 pounds to 47,000 pounds and at density altitudes from 4000 feet to 11,000 feet. Time will not permit discussion of the entire test program; therefore, only the highlights will be discussed.

Next slide (slide 3)

The control system characteristics were evaluated on the ground with the rotors static, powered by external hydraulic and electrical sources. The control breakout forces, including friction, are shown on this viewgraph. As may be seen, the longitudinal and lateral control forces exceeded the requirements of MIL-H-8501A. The control system characteristics were qualitatively evaluated in flight and found to be satisfactory for IFR operations. Incorporated in the aircraft control system to provide for increased stability during maneuvering flight and hands-off operation during cruise is an automatic flight control system (AFCS) with ±10 percent authority around trim in pitch and roll, and ±5 percent authority in altitude and yaw.

Next slide (slide 4)

The AFCS contains two independent systems, either of which may be engaged separately. However, for normal operations both systems are engaged. An oscillatory shut-off unit is provided which monitors the output of both systems and should a failure occur, the malfunctioning unit is automatically disengaged. The failure will be indicated to the pilot by illumination of a light on the AFCS control panel and depending on the major failure, may be reengaged by pressing the engage button of the failed system. Each AFCS contains pitch, roll, yaw and altitude stabilization channels. The principle of operations of each channel is essentially the same and they provide the assistance shown on this viewgraph.

Next slide (slide 5)

Pitch rate damping is facilitated through electronically differentiating pitch attitude, while roll and yaw rate damping are facilitated through signals from roll and yaw rate gyros. Attitude retention is provided through use of vertical gyros and altitude retention through use of the barometric altimeter. The ship's compass system facilitates the heading hold feature. During hands off–flight, a yaw trim control on the AFCS control panel allows the pilot to make heading changes. The failure of one AFCS does not degrade the aircraft handling qualities of the CH-54 and should not cause the mission in progress to be aborted. However, initiation of IFR operation with one system inoperative will be ill-advised since the mission would be necessarily aborted in event of failure of the remaining AFCS. The handling qualities of the CH-54B are such that with complete AFCS failure, the pilot can satisfactorily control the aircraft for emergency operations; however, in doing so, all of his attention must be directed to maintaining control of the aircraft and cannot be directed toward mission tasks or requirements. During this evaluation, all of the handling qualities of the CH-54B were assessed. As enhanced by the AFCS, the handling qualities were found to be quite satisfactory for IFR operations.

Next slide (slide 6)

The CH-54B control power was found to be well in excess of the requirements of MIL-H-8501A. The angular velocity damping required for IFR operations was found to be satisfactory for the most part. Although the yaw angular velocity damping did not meet the specification requirements, the strong control power made the aircraft characteristics satisfactory for IFR operations.

Next slide (slide 7)

IFR flight tests were not quantitatively conducted with external sling loads. The external sling load capability of the CH-54B was qualitatively assessed, carrying loads up to 16,000 pounds. It was found while transporting high-density loads in excess of 13,000 pounds, the CH-54B was susceptible to vertical bounce while approaching to a landing. This characteristic is undesirable even for VFR operations and could be hazardous during IFR operations since the motions of the sling load are transmitted to the aircraft.

Next slide (slide 8)

The adequacy of the avionics equipment incorporated in the CH-54B was qualitatively assessed. For enroute navigation, the use of a single visual omnirange (VOR) receiver required the copilot to make many frequency and course selector changes in keeping track of the aircraft's progress between VOR stations, making ground speed checks, and determining the aircraft's location. Installation of a second VOR receiver would considerably reduce the copilot's workload. In addition, dual VOR receivers would provide increased reliability. The installation of another VOR receiver is required to provide increased and more precise navigational capability.

During the instrument landing phase of our evaluation, the lack of a marker beacon receiver restricted the ILS capability of the CH-54B in that an ILS approach is precluded altogether if a marker beacon is the only available means of identifying the approach fix. The ILS approach capability of the CH-54B helicopter is further degraded by the lack of a glide slope receiver because of the increased weather minima requirements for the approach. The installation of a marker beacon receiver and a glide slope receiver is required for maximum ILS approach capability.

During our test program, an airspeed of 90 knots was established as the best airspeed to be used for maneuvering and while accomplishing instrument approaches and go-arounds in the CH-54B. The IFR capability and tactical navigational capability of the CH-54B would be further enhanced by the incorporation of additional avionics equipment such as indicated in this viewgraph.

Flight under partial panel conditions was evaluated to determine the effect of a failure in the pilot's gyro reference system. The lack of a precise attitude or heading reference system significantly increased pilot workload. However, the handling qualities of the CH-54B are such that emergency operations could be accomplished under partial panel conditions.

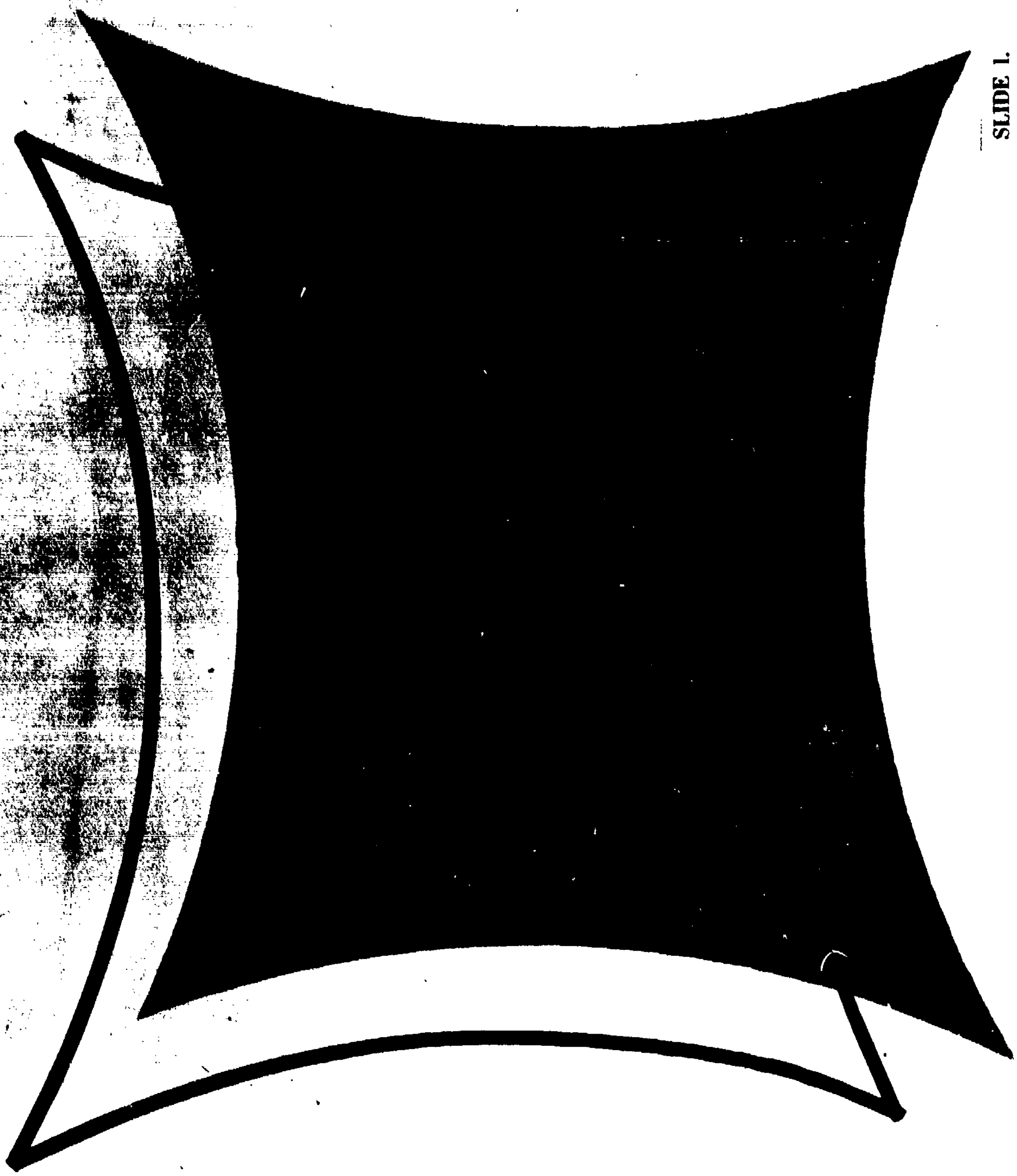
Next slide (slide 9)

The following conclusions were made as a result of this test program:

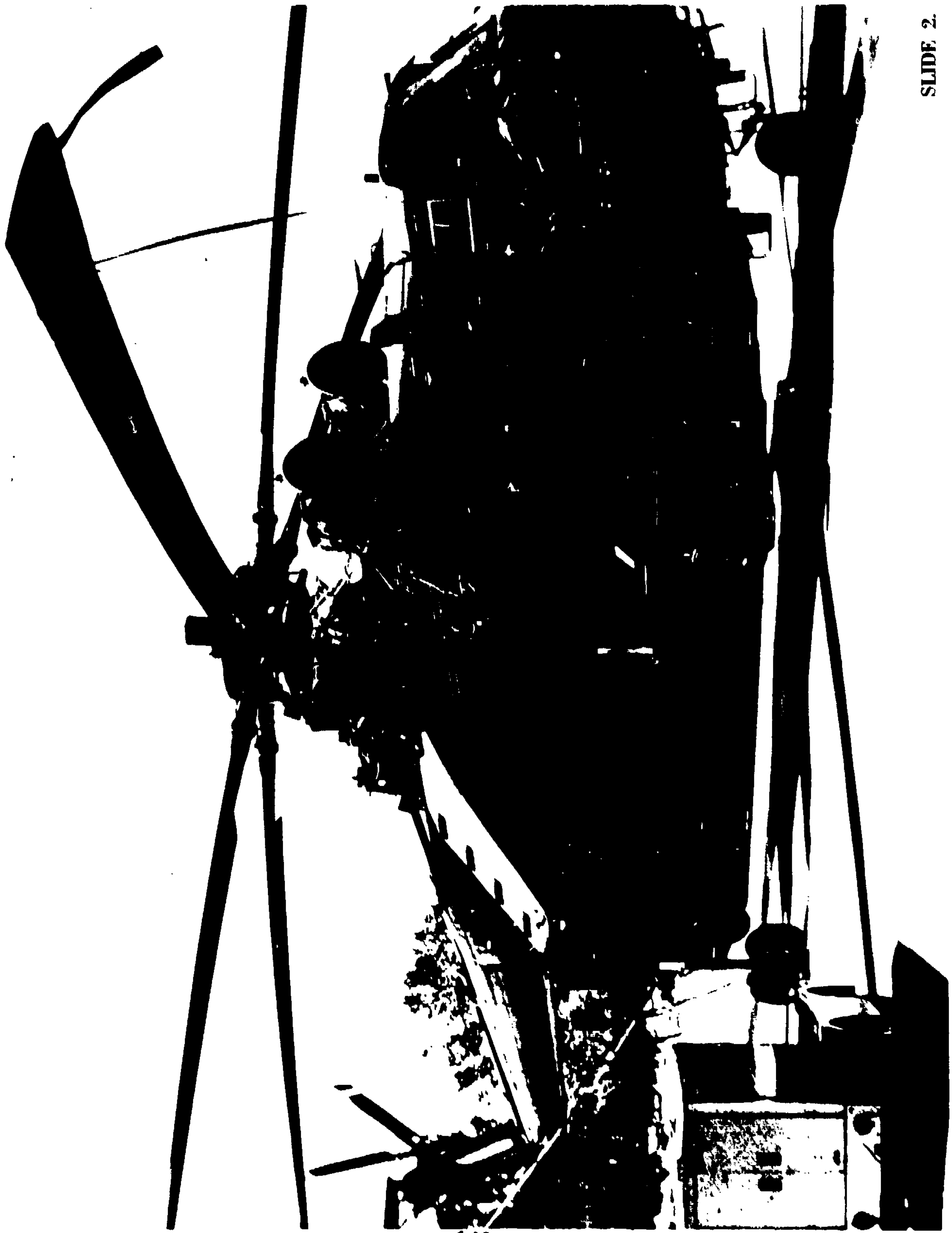
a. The flying qualities of the CH-54B, as enhanced by the installed automatic flight control systems, are suitable for IFR mission accomplishment.

b. Additional avionics equipment is required to enhance the navigational and instrument landing capabilities of the CH-54B.

NOTE: As a result of ASTA's evaluation and recommendations, an interim safety-of-flight release has been issued by the Flight Standards Office of AVSCOM allowing IFR operation with all CH-54 helicopters.



SLIDE 1.



SLIDE 2

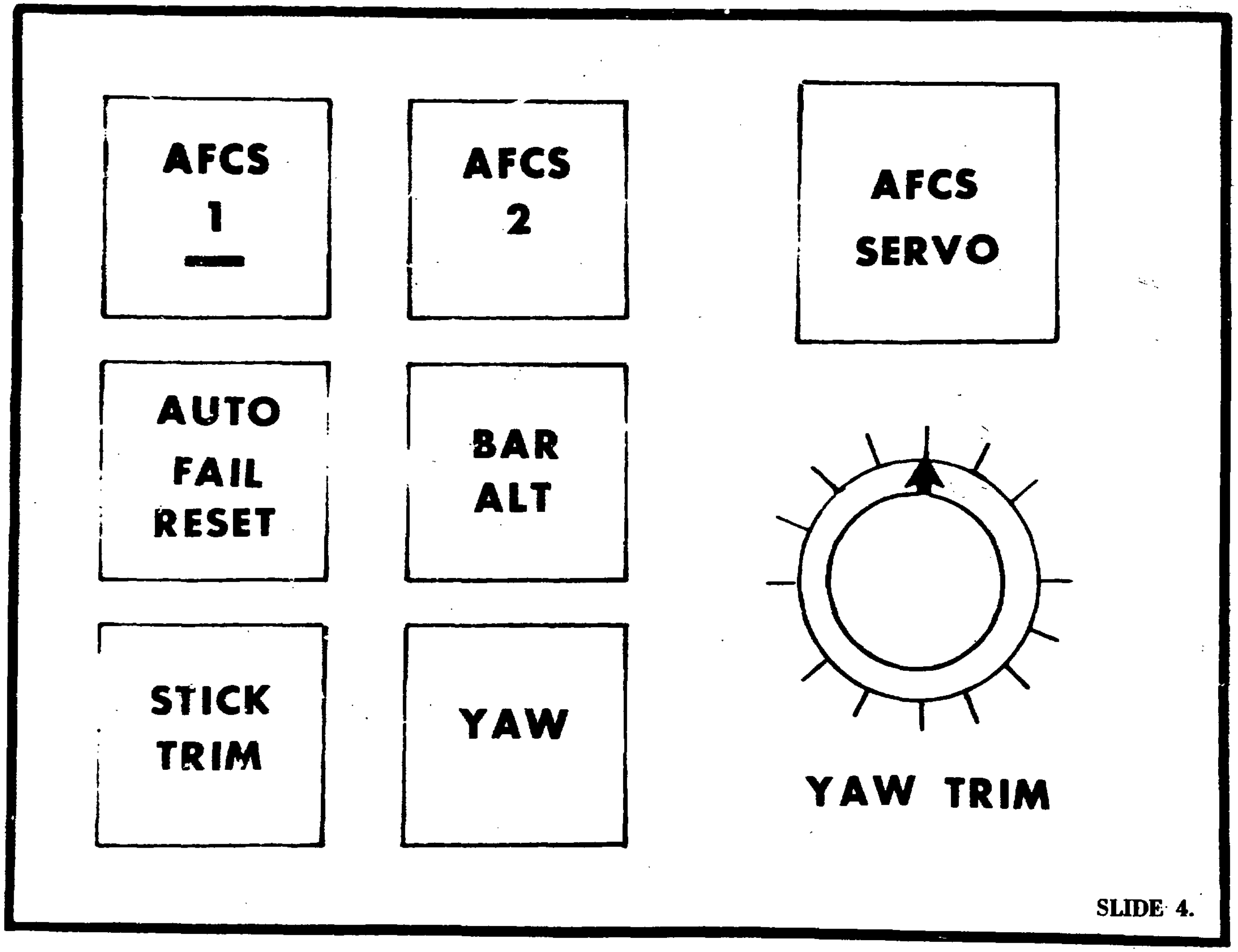
CONTROL SYSTEM CHARACTERISTICS

AXIS	CONTROL FORCE		SPEC RQMT	
			MIN	MAX
LONG	FWD	AFT	0.5	1.5
	3.4	2.2		
LAT	LT	RT	0.5	1.5
	3.8	2.2		
DIR	LT	RT	3.0	7.0
	3.0	3.0		

1. BREAKOUT INCLUDING FRICTON

SLIDE 3.

AFCS CONTROL



SLIDE 4.

AUTOMATIC FLIGHT CONTROL SYSTEM

RATE DAMPING

ATTITUDE RETENTION

ALTITUDE RETENTION

HEADING HOLD

SLIDE 5.

CONTROL POWER

AXIS	RESULTS	SPEC RQMT (8501A)	
		VFR	IFR
LONG	2.10	1.24	2.01
LAT	1.15	0.74	0.88
DIR	4.30	3.03	3.03

ATTITUDE AT ONE SECOND FOR ONE INCH CONTROL INPUT

SLIDE 6.

ANGULAR VELOCITY DAMPING

AXIS	GROSS WEIGHT	TEST RESULTS	SPEC RQMT (8501A)	
			VFR	IFR
LONG	31,000	161,421	36,356	68,168
	43,200	168,858	38,775	72,703
LAT	31,000	53,080	32,434	33,843
	43,200	88,472	34,378	47,786
DIR	31,000	83,377	113,885	113,885
	43,200	75,522	114,354	114,354

SLIDE 7.

AVIONICS

INSTALLED	REQUIRED/DESIRED
VOR RECEIVER (1)	VOR RECEIVER
ADF RECEIVER	MARKER BEACON
ILS RECEIVER	ILS GLIDE SLOPE
TRANSPONDER	TACAN
	LORAN
	DECCA

SLIDE 8.

CONCLUSIONS

THE FLYING QUALITIES OF THE CH-54B, AS ENHANCED BY THE INSTALLED AFCS, ARE SUITABLE FOR IFR OPERATIONS.

ADDITIONAL AVIONICS EQUIPMENT IS REQUIRED TO ENHANCE THE NAVIGATIONAL AND INSTRUMENT LANDING CAPABILITIES OF THE CH-54B.

SLIDE 9.

COL WRIGHT: To conclude the ASTA presentation, I'll call on Major Burden to discuss the testing which we plan to initiate on the AH-1G.

Major Burden graduated from the Military Academy in 1960, completed flight training in 1963 and graduated from the Naval Test Pilot School in 1969. He came to ASTA, November 1969, went to Command and General Staff College and came back to ASTA in June of 1971. He has participated in a number of programs with the CH-47; flew the Cheyenne in the AHRE evaluation and is now Project Officer on the Cobra evaluation.

AH-1G TEST PLAN BRIEFING

MAJOR JOHN R. BURDEN
EXPERIMENTAL TEST PILOT
US ARMY AVIATION SYSTEMS TEST ACTIVITY

INTRODUCTION (slide 1). As with the other aircraft already briefed, the AH-1G helicopter will be tested to determine the overall capability of the aircraft to operate safely in IFR conditions with emphasis on handling qualities. The AH-1G Cobra test program is about to commence the flying phase, therefore no results are available for presentation at this time. I would, however, like to present the plan of test and some of the problem areas we anticipate.

Next slide (slide 2)

AIRCRAFT DESCRIPTION. The AH-1G attack helicopter is a two-place, tandem-seated, high-speed conventional helicopter manufactured by Bell Helicopter Company. The distinctive features of the Cobra are the very narrow fuselage, small mid wings, and an integral chin turret. The test aircraft shown here is in the tractor tail rotor configuration, that is, the tail rotor is on the right side of the vertical fin. This is now the Army standard configuration. The aircraft is powered by a single Lycoming T53-L-13 turboshaft engine derated to 1100 shaft horsepower. The AH-1G incorporates a three-axis stability and control augmentation system, referred to as SCAS. This SCAS is a single system, that is, no redundancy of components, and it provides rate damping in all axes. There are no attitude or altitude retention capabilities.

Next slide (slide 3)

SCOPE OF IFR TEST PLAN. The evaluation of the instrument capability of the AH-1G will be similar in scope to the OH-58 and OH-6 IFR tests. The handling qualities phase will include the tests listed on this slide. Data obtained during previous ASTA testing will be used to the maximum extent possible; therefore, these tests will be of limited scope. Most of these tests have been previously discussed for other aircraft, but several of the tests listed have special implications for the Cobra. Previous ASTA testing of the Cobra has shown that high roll rates accompany simulated engine failure at high airspeed and/or high engine torque settings. We will be looking very critically at the autorotation tests. The SCAS system failure tests are also very important because this SCAS lacks redundancy.

Next slide (slide 4)

The tests to be conducted during the IFR capability phase, as listed on this slide, are similar to the tests discussed for the OH-6. The pilot workload and flight path accuracy measurements and analysis will be accomplished by computerized data reduction. One area of the AH-1G which is radically different from the previous aircraft discussed is the cockpit. Most aircraft have nearly identical controls for the pilot and the copilot. The Cobra, however, has sidearm controls in the copilot/gunner station which changes the workload and control motion characteristics drastically from those in the pilot station. This arrangement causes us to repeat the IFR workload tests for each station. Other areas where we know there will be problems during IFR flight include excessive canopy reflections of cockpit and instrument lights and also the autorotational characteristics I have previously mentioned. Of concern is the fact that the Cobra has only one generator. Although this test doesn't include reliability testing, it is an area which must be considered when evaluating an aircraft for IFR flight.

Next slide (slide 5)

AR 95-1 DISCUSSION. I would now like to familiarize you with the current crew and equipment requirements of Army Regulation 95-1. The copilot requirements for IFR flight in Army aircraft are shown on the next slide. As can be seen, a qualified copilot is required for all flights in rotary wing aircraft into known or forecast IFR conditions regardless of normal crew assigments.

Next slide (slide 6)

The equipment requirements for IFR flight as listed in AR 95-1 are shown on this slide. These are the minimum requirements and other equipment such as additional communications radios, a radio magnetic indicator (RMI), a course indicator (CI), dual VOR, transponder, radar altimeter, flight director, or autopilot may be desirable or necessary depending on the aircraft and mission.

Next slide (slide 7)

AH-1G COCKPIT DISCUSSION. Keeping in mind these crew and equipment requirements, I would like to take you through the cockpit of the AH-1G Cobra. The Cobra is the only tandem-seated aircraft in the active Army inventory and we have limited IFR experience in this type cockpit. The aft crew station, which is the pilot station, is shown here. As can be readily seen, space is at a premium yet the minimum requirements of AR 95-1 are not met. The following items are not present or are inadequate: the magnetic compass cannot be seen from this station, the only navigational radio is ADF which is totally inadequate for CONUS IFR operation, and there is inadequate space to use and store IFR publications.

Next slide (slide 8)

The copilot/gunner station located forward of the pilot is shown here. There are barely enough instruments in this station to fly VFR and the copilot does not have the advantage of being able to see the pilot's instruments as he would in a normal side-by-side configuration. Of the minimum required equipment for IFR flight, the following are not present: a turn and bank indicator, a vertical speed indicator, navigational radios, and space to use and store IFR publications.

Comments by GENERAL MADDOX during Major Burden's presentation on the AH-1G test plan.

"Let me explain to you. Now the requirement for this copilot is not that he be a fully qualified pilot in that aircraft. He doesn't have to be able to do everything that the pilot does; we only need one of those guys. So he doesn't have to have a dual set of everything that you have in the back of the Cobra."

MAJ BURDEN: Thank you, sir.

Additionally, the copilot has no capability to tune the ADF navigational radio or the UHF or FM communication radios. He does have the only VHF radio control panel. At this point I would like to point out the control arrangement in the copilot station. The collective control is located on the left and the cyclic control is on the right. As mentioned previously, the copilot controls have restricted movement; that is, shorter control throw to achieve the same result as in the pilot station with more conventional controls. This characteristic changes the force gradients and, in conjunction with the limited instrumentation available, makes flight from the copilot station quite difficult

PROBLEMS DUE TO TANDEM-SEAT ARRANGEMENT. The very nature of the tandem seating arrangement limits the assistance the copilot can give to the pilot and complicates crew coordination. An example of this crew coordination problem is a recent accident involving a Navy T-1 aircraft. The T-1 is a two-place, tandem seat aircraft used extensively for instrument training. The radio control arrangement in the T-1, as well as in some other tandem aircraft, but not in the Cobra, is one set of radios but two sets of control panels, one in each cockpit. In that particular configuration, each station has a radio control switch to gain control of the radios but only that crew station's frequency settings are then actually tuned into the radios. In the accident I referred to, the pilot in the front cockpit had the wrong TACAN frequency tuned in and he had radio control. The instructor pilot in the aft cockpit had the correct frequency tuned in but did not have radio control. They subsequently flew into a mountain while in instrument conditions and there were no survivors. This is but one vivid but tragic example of the difficulty experienced during IFR flight in tandem aircraft.

The problems I have discussed and many other problems that have arisen because of the tandem configuration will impact greatly on IFR flight. We invite your participation in their solution.

INSTRUMENT-FLIGHT-RULES EVALUATION

AH-1G HELICOPTER

WITH TRACTOR TAIL ROTOR

MAJOR JACK BURDEN, US ARMY

SLIDE 1.

PRODUCTION MODEL, AH-1G ATTACK HELICOPTER

SLIDE 2

AH-1G IFR EVALUATION-HANDLING QUALITIES PHASE

CONTROL SYSTEM CHARACTERISTICS

CONTROLLABILITY

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

STATIC LONGITUDINAL STABILITY

STATIC LATERAL-DIRECTIONAL STABILITY

DYNAMIC STABILITY

AUTOROTATIONAL ENTRY CHARACTERISTICS

AUTOROTATIONAL DESCENT CHARACTERISTICS

STABILITY AND CONTROL AUGMENTATION SYSTEM
FAILURE CHARACTERISTICS

SLIDE 3.

AH-1G IFR EVALUATION-INSTRUMENT FLIGHT RULES CAPABILITY PHASE

COCKPIT EVALUATION

INSTRUMENT FLIGHT AIRSPEEDS

INSTRUMENT FLIGHT MISSION PROFILE

PILOT WORKLOAD

PARTIAL-PANEL CHARACTERISTICS

NIGHT INSTRUMENT FLIGHT CHARACTERISTICS

UNUSUAL ATTITUDE RECOVERY CHARACTERISTICS

INSTRUMENT FLIGHT AUTOROTATIONAL ENTRY CHARACTERISTICS

INSTRUMENT FLIGHT AUTOROTATIONAL DESCENT CHARACTERISTICS

SLIDE 4.

AR 95-1 COPILOT REQUIREMENTS FOR IFR FLIGHT

➧ ➧ ➧ A COPILOT, INSTRUMENT RATED IN EITHER CATEGORY AND PROPERLY PRE-BRIEFED FOR THE FLIGHT, IS REQUIRED FOR ALL FIXED AND ROTORY WING FLIGHTS INTO KNOWN OR FORECAST INSTRUMENT CONDITIONS.

NOTE: COPILOT REQUIREMENTS ARE WAIVED FOR OV-1 AIRCRAFT WHEN REQUIRED BY MISSION ASSIGNMENT.

SLIDE 5.

AR 95-1 EQUIPMENT REQUIREMENTS FOR IFR FLIGHT

AIRSPEED INDICATOR

SENSITIVE ALTIMETER

TURN AND BANK INDICATOR

CLOCK/WATCH (WITH SWEEP SECOND HAND)

COMPASS (WITH CURRENT CALIBRATION CARD)

ATTITUDE INDICATOR

HEADING INDICATOR

VERTICAL SPEED INDICATOR

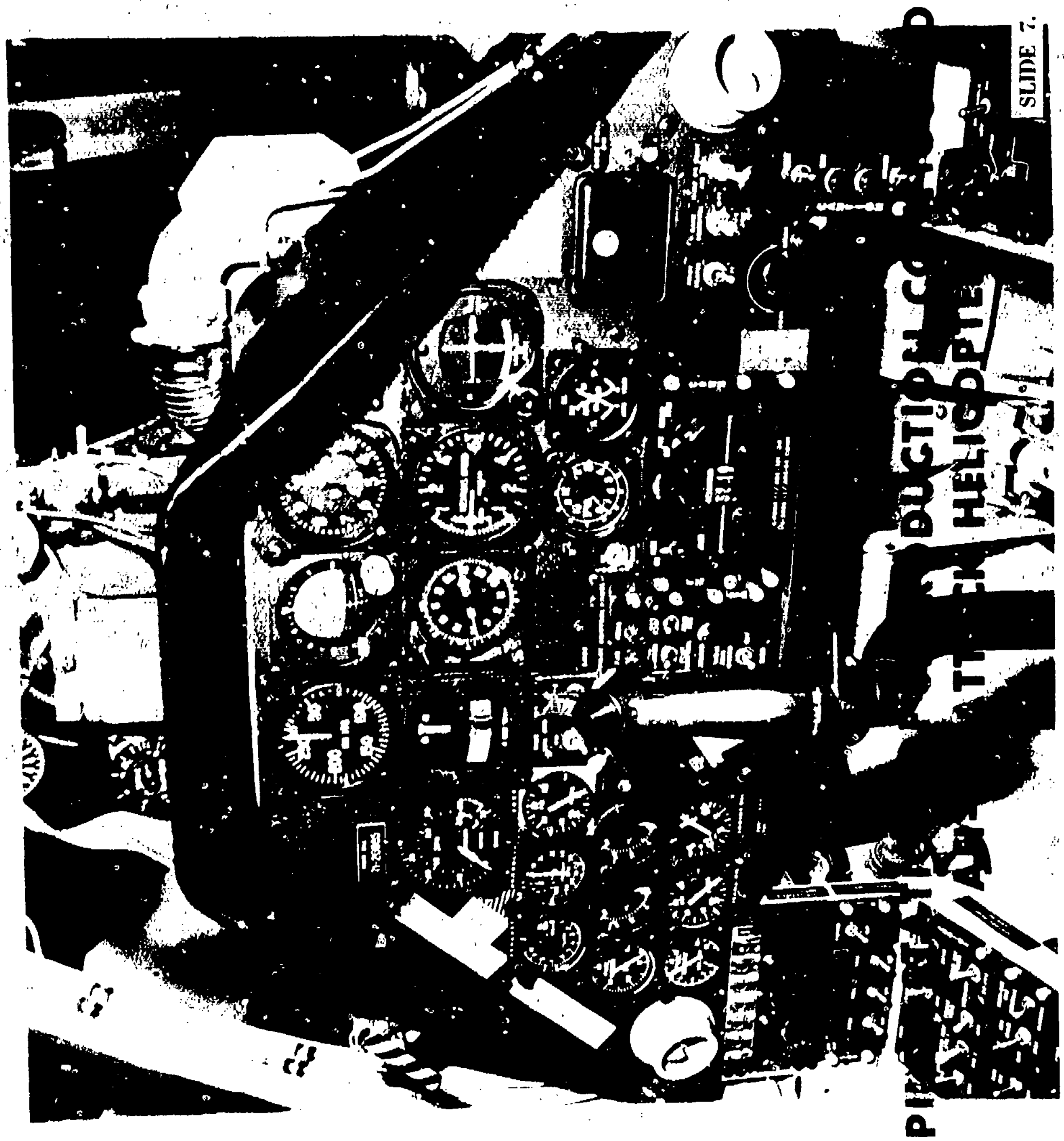
RADIO TRANSMITTER AND RECEIVER

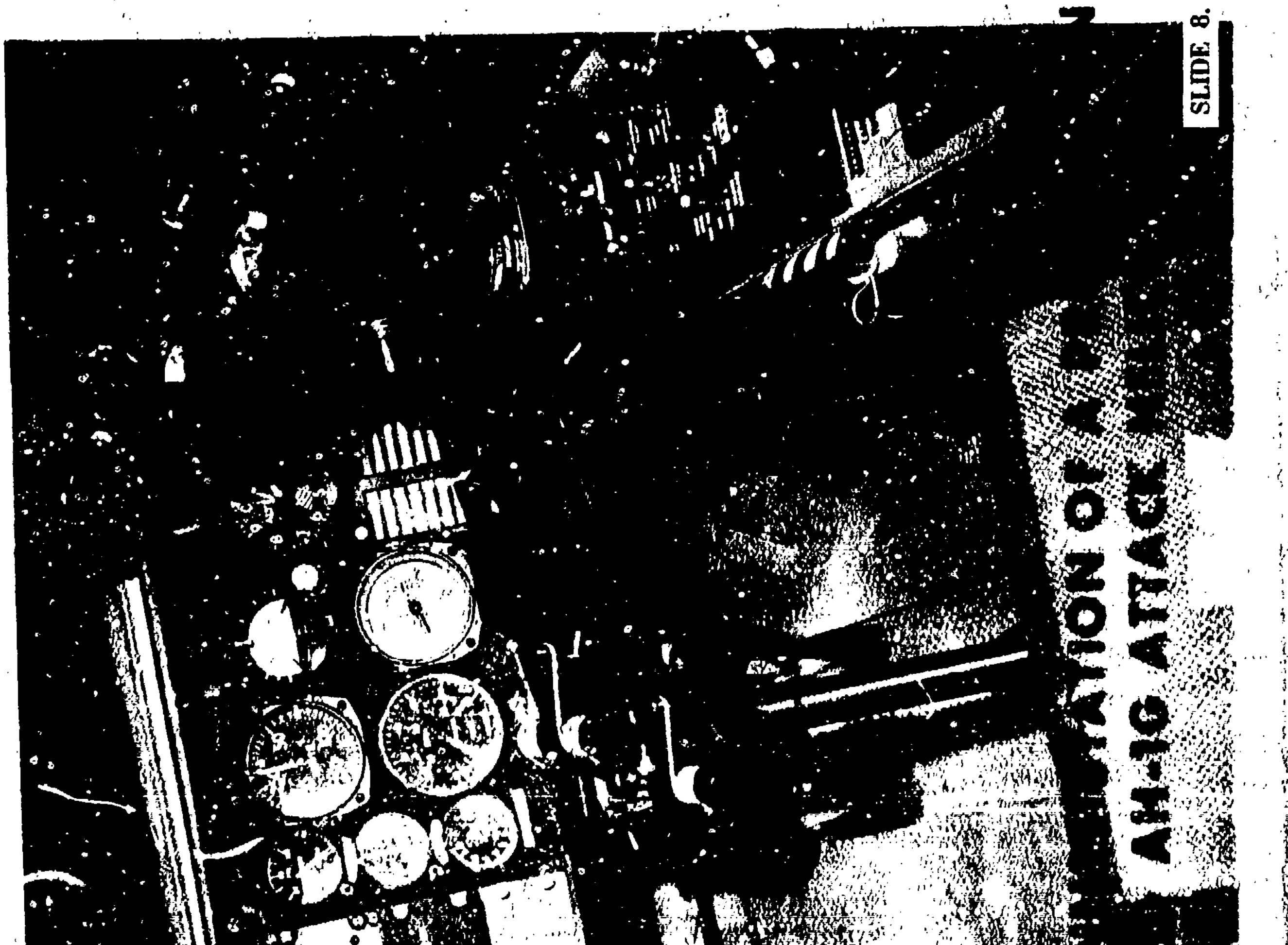
APPROPRIATE NAVIGATIONAL RADIOS

PITOT HEATER

CURRENT PUBLICATIONS (AVAILABLE TO THE PILOT)

SLIDE 6.


SLIDE 7.


SLIDE 8.

GENERAL MADDOX: May I say a word. I'd like to put things in context here because we have been listening to quite critical comments on our aircraft by some very competent specialists. I do not want anything I have to say to reflect on their criticism because that's what the test pilots are paid to do and I think they do it in a damn fine manner. However, I do want to put this whole thing into the context of the operator, whom I represent.

At the present time our intention is to develop a new series of aircraft. The AAH, the HLH, and UTTAS are coming along. There is a pending new development for a true aerial scout, not a new light observation helicopter, but a true aerial scout. Then we have a series of product improvement programs already in the works. But our immediate problem right now is to figure what we can do with the current machines on the flight line to get them to be, minimally at least, capable of performing instrument flight. We must make those aircraft do more than they can do at the present time and in doing that we must make the operator more capable of milking out of the aircraft everything that's built into them. And we do not have unlimited funds for modifications and retrofits.

Realistically, we're not going to have an optimum situation in most of the aircraft that we fly at the present time. If the stick doesn't migrate back to where it should, we can learn to live with that, even if it exceeds the Military Specification requirements. We can learn to fly with many of the current deficiencies and, in most cases, this is exactly what we're going to have to do.

Now, I would ask a couple of questions. Are the standards that we have stated in the Military Specification really what we must have or are they good goals? Can we settle with some sort of waiver or exemption with something less than the full standard? What are our minimum standards? What is the tradeoff between cost and comfort? These are questions that we should take from this conference, mull over at length, reassemble on another occasion, and try to resolve. We must adjust our thinking on current aircraft because I am convinced that we are going to have to drive many of these aircraft on instruments in substantially the situation they are now, plus some modest improvements.

For example, putting a second generator on the Cobra makes sense and we have a project in being to do this. I'm told for $8,000 we can do it. More extensive modification probably isn't justified. We are probably going to have to improve our LOH fleet, at least the part of it that mills around where it is liable to get into inadvertent IFR. The other things that are identified will have to be weighted against costs involved and safety considerations. We have a lot of money involved in this aviation picture and it has been applied in fairly liberal amounts to aircraft. However, there is going to be less of it available. I'm sure you saw on your television this morning the crabbing about the defense budget presented to the Congress yesterday. We have to measure what we do to the aircraft and to modify them very carefully.

Copilot requirements in AR 95-1 have been reduced. There are pilot duties and copilot duties; we have tended in the past to require that the copilot do everything the pilot does. The new regulation requires that a copilot only be at least qualified in the duties that he can normally be expected to perform in his copilot status. Therefore, he does not have to have an entire panel and navigational aids and radios in the front of a Cobra that the pilot has in the back. The same thing goes for the side-by-side business between the two drivers.

At any rate, let's go positive in this IFR business because it gives us substantially greater tactical capability, and let's figure what we can do rather than why we shouldn't do things.

Thank you very much.

SESSION II

Panel 1

HELICOPTER IFR EFFORTS OF OTHER GOVERNMENT AGENCIES

MODERATOR

COLONEL JOHN C. GEARY
AVSCOM

PANELISTS

MR. JOSEPH MASHMAN, HAA

CAPTAIN WILLIAM COLEMAN, TECOM

MR. OTTO SCHOENBERGER, ECOM

COMMANDER DONALD E. BECK, NATC

MR. JOSEPH F. WINTER, USAF

MR. JOHN GARREN, NASA

MR. DENNIS TUCK, FAA

PHOTO 1. SESSION II. PANEL 1.

PHOTO 2. SESSION II. PANEL 1.

INTRODUCTION OF PANEL BY COLONEL GEARY

COLONEL JOHN C. GEARY
DIRECTOR FOR RESEARCH, DEVELOPMENT, AND ENGINEERING
US ARMY AVIATION SYSTEMS COMMAND

Okay, now that we've got the word on what our objectives are, and what we in the Army are doing, I have been selected to chair the panel on helicopter IFR efforts of other government agencies, and I haven't yet quite figured out how the Helicopter Association of America is another government agency. But, at any rate, as seen through the program, our objective here is to try to get as much of a cross section view of what everybody is doing in this business; if we are pointed in the right way; and if we are not, to get at least a collective relative position in order to achieve the desired results.

But the message comes out loud and clear that with the reduction in the current projected expenditures for government hardware and specifically, government helicopters, it looks like we are going to have to live a little better with what we have. And with that, I know that the Helicopter Association lives with what we have, and are making the most of it.

In setting up this panel, we didn't get quite as formal as Colonel Wright with his ASTA panel, where he had formal presentations. I noticed by the agenda we were permitted 45 minutes; we have seven speakers; as a result, that allows each one about 6 minutes, with a little time to get up from his seat to come up here and go back, and if there are any questions, we will entertain them as the opportunity comes up. So without formal presentations, then, just a session – a little discussion – on what each representative is doing, what their objectives are, and some insight as to what their problems are, I would like to start off with Joe Mashman, Bell Helicopter, representative of the Helicopter Association of America, with the opening comments.

JOSEPH MASHMAN
HELICOPTER ASSOCIATION OF AMERICA

The Helicopter Association of America is an association of helicopter operators that was founded 25 years ago and is representative of commercial and private operators throughout the free world. Manufacturers of helicopter airframes, engines, avionics, and components participate in this organization as associate members. This organization's members have a combined fleet of aircraft in excess of four thousand whose annual accrued flight time is approximately double that of comparable fixed-wing type of operations. Our members include airlines such as KLM, United, San Francisco, Oakland, Chicago Helicopter Airways and British European Airways. Several operators have fleets of approximately two hundred aircraft, although the majority of our operators range in the 5 to 15 aircraft size. Our operator requirements vary from those operating a medium to large transport type of equipment under IFR conditions in the North Sea and off the shores of Canada and Alaska to the majority of the operators who are presently limited to VFR flight operations because of their aircraft's lack of IFR capability.

The basic objectives of our organization include:

1. Greater productivity of our equipment.

2. More effective response to user and public needs.

3. Improvements in all aspects of operational safety.

The concept of IFR flight obviously can favorably influence these objectives. Although the majority of our operators are achieving a high percentage of flight completion, the additional flights made possible by IFR capability would provide a significant economic benefit to the operator and assure a more uniform and professional type of operation.

As a result of a number of meetings and panel discussions that our organization has conducted with its members we have arrived at the conclusion that well over 90 percent of the operations are conducted in what might be termed as medium to low density air traffic conditions.

Our needs can best be summed up as follows. We request our government to:

1. Establish a means of certifying helicopters for various levels of traffic density as relating to crew requirements and installed equipment.

2. Relax present aircraft IFR stability requirements when type of operation assures equivalent safety.

3. Encourage rotorcraft manufacturers to provide IFR capability in the design concept of new aircraft models.

4. Provide the FAA air traffic control system and helicopter operators with a guide for routes and procedures that will enable helicopters to operate under IFR conditions within our present air traffic system with minimum impact on our nation's fixed-wing traffic.

5. Establish a realistic criteria for determining helicopter ability to fly in icing conditions.

6. Encourage the acceptance of our FAA's helicopter certification standards by other nations of the free world.

COLONEL GEARY: Thank you, Joe.

MR. MASHMAN: How long did I take?

COLONEL GEARY: Eight minutes. That's the first time he has been late on an ETA that I know of. It's easy to see that the commercial operator's objectives are somewhat similar and complementary to those that General Maddox mentioned from the Army point of view.

Now, let's take a look at what our Army Aviation Test Board activity at Fort Rucker is doing, and to represent the test board, we have Captain Bill Coleman, who has been involved in the flight test programs to determine military potential for three different flight directors. He has several hundred hours of experience with these flight directors, which have been taken throughout the Army to several military installations to brief them, to let people see what they can do and to concur or additionally evaluate them. Captain Coleman has been associated with the Aviation Test Board here – let's see – he went to Vietnam in 1969 – has been with the Aviation Test Board for nine months, so he has a busy nine months.

CAPTAIN WILLIAM E. COLEMAN
US ARMY AVIATION TEST BOARD

The Army Aviation Test Board has been testing and evaluating helicopter instrumentation since 1957. During the period 1957 through 1959, there were ten separate projects covering stabilization equipment, flight directors, instrument presentations, absolute altimeters, vertical speed indicators, and a doppler navigation system.

When the LOH was on the horizon with its requirements for a 180-degree turn capability, several lightweight heading and attitude indicators were evaluated. It was soon learned that the instruments designed for use in light airplanes would not survive in light helicopters. When the LOH was delivered for TECOM's evaluation, it was equipped with an attitude indicator that was designed for helicopter use and these instruments did survive, clearly supporting the need for flight instruments designed specifically for helicopter use. Subsequent to these tests, there have been evaluations of individual items to determine if they do enhance helicopter instrument flight, but until 1972, there has been no major coordinated effort to evaluate existing commercially available equipment, or to redefine helicopter instrument flight requirements.

In 1971/72, a military potential test of three different off-the-shelf flight director systems was conducted. During this test, the Aviation Board was to determine if flight directors in general enhanced the "possible" IFR capability of the OH-58 helicopter. Each system was flown a total of 250 hours within the vicinity of Fort Rucker, Alabama, under simulated instrument flight conditions. The manufacturer of each flight director system trained project personnel in the use of his equipment. Project aviators each received a 2-hour ground school covering the modes of operation of each particular system; upon completion of the ground school, the aviator received a 3-hour block of in-flight instruction with an instructor pilot. During this phase of his training, the instructor pilot demonstrated the use of the flight director in all normal aspects of IFR flights. For example, an instrument takeoff was performed with a climb to an assigned altitude. Then a maneuver to intercept a desired radial, utilizing the VOR mode, was accomplished. ADF, VOR, ILS, and back course localizer approaches were also demonstrated. After only 3 hours of in-flight instruction, project aviators with no previous flight director experience were capable of using the flight directors as required to perform an assigned task. The area of evaluation that was of particular note in this test was the degree to which the pilot workload was reduced by the flight director. Two of the three systems tested incorporated an altitude-hold mode that presented the selected altitude on the attitude indicator and would alert the pilot any time he left that altitude. This mode considerably reduced the need to cross-check the barometric altitude indicator on every scan. Another workload reduction feature was the installation of a ball and race within the lower portion of the attitude indicator, instead of the present location of the turn and bank indicator at the bottom of the instrument panel. All three systems had an automatic feature in the ILS mode of operation to compensate for crosswind conditions. Again, the effect was a reduction of the pilot workload required to determine the direction and velocity of the wind while on final approach. Aviators have demonstrated a higher degree of efficiency when flying an aircraft with a flight director than with those same type helicopters that are not so equipped. To obtain quantitative data, a limited test was conducted by the Aviation Test Board to determine aviator time saved during a flight profile in which a flight director system was utilized. Project personnel were given a test designed to determine workload advantages of the flight director system over the conventional instrument display. Each aviator was required to solve and perform, in his head, a series of four mathematical problems, under controlled conditions, using no mechanical means to aid in the computations. The computations were adding two double digit numbers and dividing by a third single digit number. The aviators were timed during each series of computations, under each test condition. The average time to solve the problem series, by condition, was computed and recorded. The averages, under the controlled three conditions, were compared to determine whether or not the pilot workload was reduced.

It was determined that instrument flight utilizing a flight director system, as compared to the conventional system, was considerably less demanding of the pilot. Helicopter modifications required to install the FDS were minor and consisted mostly of relocating or replacing existing equipment. The weight of the flight director systems caused no appreciable loss to the mission capability and did not adversely affect the center of gravity of the OH-58 helicopter.

Although lighter and more reliable, the systems tested are no different in concept than those tested ten years ago, and like the ones previously tested, these systems are designed for use in fixed wing aircraft. Flight director systems, specifically designed for helicopter use, are needed particularly to provide pitch commands for initiation of climbs and descents.

COLONEL GEARY: I guess the solution to success there is cheap flight director systems and we'll buy them and install them.

Okay, now let's take a look at what we are doing in the avionics area, and for that we have Mr. Otto Schoenberger, who is Technical Director of the terrain avoidance team at Avionics Laboratory, Electronics Command. He is responsible for planning direction and the conduct of R&D in areas of terrain avoidance, low-altitude control of aircraft, collision avoidance, and airborne radars. Mr. Schoenberger also has a helicopter pilot rating, so he speaks with some degree of authority and experience, as well as technical competence.

OTTO SCHOENBERGER
AVIONICS LABORATORY
US ARMY ELECTRONICS COMMAND

Thank you, sir. I would much rather you had not mentioned my being a helicopter pilot. Looking around in this room, just about everybody has tens-of-thousands of hours of pilot experience in just about every kind of airplane and helicopter. Whatever little experience I have really doesn't count in view of this.

The Army Electronics Command has a variety of R&D projects in progress, or on the books, and I have selected what I consider to be a representative cross section of those Army projects that may provide a data base for the IFR effort we are talking about here. Obviously, in the relatively short time I cannot even give you the few selected programs in the detail you might want to hear.

The program closest to my heart is the Automatic Terrain Following/Terrain Avoidance program which we started back in 1965/66. Basically, we performed a terrain avoidance/terrain following concept evaluation utilizing a terrain avoidance radar from the Joint Army/Navy Integrated Helicopter Avionics System development. We installed this radar in a UH-1B and operated it in a variety of TA/TF concepts, starting with a fixed beam forward looking altimeter type operation through the entire spectrum of TA/TF modes up to shades-of-grey type concept which provides terrain avoidance and terrain following information to the pilot simultaneously. In order to allow us to evaluate manual versus automatic low altitude operation, we developed a 4-axis automatic flight control system utilizing the basic ASW-12 automatic pilot manufactured by Sperry. The major differences of this flight control system from any known conventional type flight control system are in 80 percent control authority in the collective axis and in the fore-aft cyclic axis. This was considered necessary for automatic terrain following, and as the flight tests progressed, the need for this high authority in the two axes was continuously verified. In fact, over the extremely rough terrain at Fort Huachuca, Arizona, where the flight tests were performed, once in a while we ran out of cyclic authority.

The flight control system, prior to our evaluation, underwent a safety-of-flight evaluation done by ASTA. We considered this evaluation to be extremely thorough and for the first time, it allowed the Army to really get a handle on what the characteristics of an automatic flight control system in a helicopter should be, what it should do, and what it should not do. ASTA has published a report on this which we think should be used as a data base when taking a look at automatic flight control systems in helicopters.

There are a few results of this flight test I would like to mention. Obviously, the automatic control system does not fatigue. In manual terrain following with the pilot in the loop and despite the fact that there wa safety pilot sitting next to him, after several hours of flying, the actual terrain following objective wasn't so apparent in the flight test data any more. It turned out to be more of a peak-to-peak type flying than staying at the desired clearance altitude and going down into the valleys.

Another aspect of the flight test results concerns experience levels of pilots. For the flight tests we used four groups of experience levels of pilots. Firstly, inexperienced, just fresh out of flight school. Secondly, very experienced Army aviators with instrument flight time in excess of 1000 hours. The two remaining categories were in between these experience levels. Best performance was not turned in by the most experienced pilots. The two categories in between performed best in manual terrain following. We have an explanation why the low-experience pilots didn't do so well; they just didn't have the capability and/or the ability. We had to look around a little, however, to come up with a reason why the pilots with higher experience didn't do so well. Without pretending to be an authority in these matters, we came to the conclusion that "you can't teach an old dog new tricks."

Along these lines, we have a program now in progress called AHAS (Automatic Helicopter Approach System). We are installing an ASCAN landing system in the helicopter, developing a coupler from the AHAS into the automatic flight control system, and we will perform a flight test program this year on automatic approach. Notice that I am not saying automatic landing. Basically, what we are trying to do is a flight test evaluation to come up with a data base for automatic approach concepts. Basically, we are setting the system up for variable approach angles from approximately 3 degrees to, in the vicinity, of 16 degrees variable approach velocities, and automatic deceleration to zero airspeed at 50 feet. The automatic deceleration is being performed as a function of the range to the ground portions of the ASCAN system. Again, this program, as I mentioned earlier, but I do not want to stress this, is supposed to provide and will provide a data base effort on automatic helicopter landings. We will have, throughout this program, also the capability to attempt to manually perform, with the use of a flight director, the same functions the automatic flight control system performs, and we will, as such, be able to compare manual versus automatic performance.

Now briefly, I would like to mention the third program. One of our friends from the Air Force is going to talk a little bit more about this. We presently have going on right here at Edwards Air Force Base, a joint Air Force/Army flight test program as part of the Air Force PAVE-LOW program. Basically, it's a Cheyenne terrain avoidance and terrain following radar installed in an HH-53 night rescue equipped Air Force helicopter. As I mentioned before, Mr. Winter from the Air Force will give a more detailed description of that program later.

COLONEL GEARY: We in the Army think our helicopter IFR problems are somewhat peculiar and those that try to live in the environment are convinced that they are, until you start hearing the tales of the other services and the kinds of problems they have got. I think our next speaker, Commander Beck, is going to tell us about the inkwell environment.

Commander Donald Beck is the head of the Flight Test Rotary Wing Branch at the Naval Air Test Center. He is a Naval Test Pilot School graduate and he's been at Pax River for three years as project pilot as well as instructor at the school. He is currently one of two Navy pilots in the Canada-UK triparty evaluation of a nonhelicopter V/STOL machine, the Canadair CL-84.

COMMANDER DONALD E. BECK
FLIGHT TEST ROTARY BRANCH HEAD
US NAVAL AIR TEST CENTER

Before we can discuss the Navy's efforts in IFR flying, it is essential to define what we mean by an "IFR" Navy mission. When we think of IFR in the Navy, we think of flying on, off, or around a ship at sea at night at low altitude with no visible horizon. In other words, our mission completion is geared towards 100 percent on the gages, or as we say, in the "ink bottle" environment. ASW (antisubmarine warfare) has long been a primary mission. It is not uncommon to fly a 4.5 to 5 hour ASW mission on a black night and never get above 200 feet altitude over water. Needless to say, having a good instrument platform, good instruments, and an adequate AFCS is paramount to mission success. A good, reliable radar altimeter is a key lifeline to a Navy helo pilot. Many of our missions also require unique IFR equipment, such as an automatic approach and hover coupler. Our past experience has shown that going from 150 feet and 60 knots forward flight to an extended 30- to 50-foot stabilized hover over water requires this gear. It might sound strange, but the "ink bottle" IFR environment is so rigorous that it is easy to get sensations you are backing down, going forward, left or right, when the opposite direction or a stable condition is the true aircraft hover condition. Without adequate automatics and instruments, I can assure you we would lose many aircraft, despite the fact that the basic aircraft stabilization is fairly good. Our sonar dipping mission often requires 5 to 20 minutes extended hover over a sonar dome where altitude control (±5 feet) and aircraft movement (±5 feet) in any direction is the key to proper sensor operation and protection from damage. Aeromedical data have shown that our extended helo ASW night missions are more fatiguing than any Navy mission.

While low ceiling and visibility may be the biggest hazard to mission completion in overland missions, they are not necessarily the most critical in the Navy helo overwater mission. Running into a ship's TACAN mast or colliding with another ASW aircraft is our biggest worry. We usually require either positive radar contact or a hard altitude separation band. In a tactical area, normally, the helos get 150 feet and below and the fixed wings get 200 feet and above.

Sea state and shipboard turbulence is a big enemy to us at sea and often severely complicates our mission in VFR and makes it extremely hairy in IFR. Getting the aircraft spotted, launched, and recovered is a big problem. Our present black night launch procedures are flown entirely by manual mode – trying to get near-optimum winds across the deck and waiting for a near-level deck condition prior to launching. A ship's deck rolling ±20 degrees every 5 to 9 seconds or deck pitches of ±20 feet can severely complicate matters. In addition, many of our takeoffs require a slight "back down" or "slide out" to avoid superstructures, missile launchers, and other objects that are not desirable for rotor blade contact.

It took the Navy a long time to get smart and start using visual landing aids in shipboard recoveries. Our fixed wing brothers stole most of their ideas from the "Brits" over twenty years ago. Our old intercept approaches and slide-across-the-deck type landing approaches to a moving platform were not conducive to good safety records. Our landing safety has greatly improved and "fly-in-the-water" accidents reduced since we went to "meatball" or "glide slope" night landing aids. However, we are presently shifting over major helo operations from large type carriers to small destroyer type platforms where conditions were most critical. When tail wheel clearances and rotor blade clearances are often measured in inches instead of feet, good aircraft stability and control and good visual landing aids are very important. A pitching and rolling deck, a black night, and steel obstacles in front and around your rotor blades demand that you "stack the deck" in favor of the pilot. We have incorporated shipboard glide slope indicators, line-up lights, extended centerline lights, floodlights, and lighted landing signalman (LSM) suits. It is still quite uncomfortable trying to get on deck within inches of the desired touchdown spot, and usually within 5 degrees of the desired lineup. It is also critical when one considers your hovering altitude and your scan for landing without reference to any horizon. (You are spotting the deck and following instructions of deck personnel to a touchdown.)

So – that is a quick review on why the Navy demands a good AFCS system to alleviate pilot workloads. However, I must say we will not let these systems degrade the basic maneuverability. We also need them to reduce our landing accident rate at the end of a 2 to 6 hour mission when pilot fatigue is greatest.

So, our instrument problems are unique. We consider shore-based GCA's or instrument approach in a non-AFCS aircraft to weather minimums to be much less demanding than our normal shipboard ops. We are looking forward in the future to a complete automatic system of shipboard takeoffs, approaches, and landings in VTOL aircraft. We are presently making shipboard arrestments "hands off" in F-4's on attack carriers. The technology is available. Bob Buffum, our AFCS specialist at Pax, will discuss our requirements and efforts in the future on the next panel discussion.

GENERAL MADDOX: Let me respond to that because I'm also in the safety business. We started out taking figures in 1957 or 58. We were running somewhere close to 60 accidents per 100,000 flying hours. I forget what the '69 figures were, but in 1970 we were running about 15 accidents per 100,000 flying hours. Last year we were down to 11.95 per 100,000 flying hours and already this year, as of the end of the first quarter, we're down under 11. This has been done with a great deal of effort on the part of trainers and on the part of the people who improve our aircraft.

There are two major considerations bearing on safety that no other Service has. We must understand both when we are training and building aircraft. First, we operate in a regime on the battlefield that just can't be equaled. It's equivalent to making a carrier landing constantly, instead of just one every so many hours. We operate very close to the earth and into very confined areas with loaded machines and people scrambling onto and off helicopters. Operating in that type field environment, we are more accident liable than if we were in a relatively pristine environment at altitude and moving from point A to point B.

Second, our experience level is very low. I've got a son who is a nineteen-year-old warrant officer. He's flying an OH-6 Scout in Can Tho today. We graduate guys from flight training at 210 hours. He got 210 hours and his 211th hour is in combat. In the year 1969, we produced a total of 6700 warrant officers and lieutenants who got their 211th flying hour in combat.

So when you look at the accident rate, you must put it in the context of the environment in which we operate, and the specific training problem that we have of putting a brand-new, shiny-winged aviator in to face the enemy.

Further, we have a statistical consideration that is unique. Here is how we sort out accidents and combat losses. Unless an aircraft is hit by hostile fire, we call it an accident. In other Services, if you go flying out and crash off the end of a carrier while lugging a bomb into Hanoi, that's a combat loss. It's not that way in the Army. If you're coming out of a hot landing zone and you're not actually fired at, then it's an operational loss and shows up in the accident statistics.

COLONEL GEARY: Thanks for a very good insight, Don, into the Navy's way of life with helicopters. Charley, we've got another requirement for Army qualification. We'll run them off a hangar deck – I mean, off of a flight deck – and see how well they do; if they do well there, I'm sure the Army environment will be acceptable. Don's mentioned that you stand there 15 or 20 minutes in a hover and the first thing you know, you don't know if you're going up or down or backwards.

Now, let's get an engineer's insight into some of these kinds of problems that Don has mentioned and all of his predecessors have mentioned. We have Mr. Chip Winter of the Flight Dynamics Laboratory, Wright Patterson AFB, to give us a little insight into the kind of things they are doing.

Mr. Winter is currently a project engineer working at the Flight Research and Test Branch of the Air Force's Flight Dynamics Laboratory and his present assignment is on a pilot factors program for the Huey trainer that the Air Force has. Chip will cover the Air Force efforts on the CH-3E IFR technology program, H-500 research vehicle, some comments on his pilot factors program, and even one critical and more difficult IFR program, the Adverse Weather Search and Rescue Program.

F. J. WINTER, JR.
FLIGHT CONTROL DIVISION
AIR FORCE FLIGHT DYNAMICS LABORATORY

Slide #1

When I was first asked to give an overview of USAF Helicopter IFR programs, I was told I had 12 minutes to talk and that was a challenge, and now I have 6 minutes, and that's an impossibility. But I will try to cover the various USAF projects as rapidly as I can. Inasmuch as the majority of you people are not familiar with what the Air Force is doing, I do think it is important that we give you at least a slight introduction and exposure for possible future technical interchange.

Slide #2

The USAF Aerospace Rescue and Recovery Service has a validated requirement to expand the current VFR Night Rescue System that they currently possess. They want to be able to go in for a rescue pickup at low levels in order to survive in a hostile environment and they also want and need an IFR capability in order to effect an adverse weather rescue. So, to make this system, we need a forward looking radar which is required for terrain avoidance and terrain following at low altitudes. We need more precise enroute navigation and also a terminal area navigation capability where we can get from the survivor range and bearing information to the rescue vehicle.

We have deployed an ELF system, which stands for Electronic Location Finder, and we have made some successful recoveries with this system. This is a big step toward solving the terminal navigation problem utilizing standard aircrew survival radios.

Night vision equipment consists of a lowlight level TV and also night vision goggles for the crewmembers. Both flying crewmembers have individual TV monitors.

The approach and hover equipment we have on board the aircraft is very similar to that which Commander Beck just described in use by the Navy. In the approach mode, we get a constant rate of descent and a constant rate of deceleration once it is engaged. In the hover mode, we can establish and then hold a stable hover, with respect to velocity.

So far, we have deployed the HH-53 VFR night rescue system, which consists of the night vision and the approach and hover coupler equipment that I just described. We've evaluated a forward looking radar that we borrowed from the Army and from tests just completed it looks like we will be able to terrain avoid and terrain follow at low altitudes.

Status: Now what we have actually testing is just the radar. In order to completely satisfy Rescue's requirement, we are going to need an improved navigation system, a 3-cue flight director system, a projected map display, and the ELF system I mentioned, coupled into the automatic hover capability. What we are doing now is trying to come up with the integration of these equipments. In the future we want to take this integrated system and fly it. We feel the need to fly it in order to come up with the now very popular preproduction prototype that the Air Force likes. We also need to be able to take a look at how valid the performance requirements are that we are now in the process of establishing. And what I mean by that is, "Do we need a stable hover within ten feet of the survivor; or is it five, or is it twenty? What are some of the numbers?"

Currently, fleet retrofit is not firm. There have been no funds identified, but efforts are being made to request the necessary funds at Air Staff level.

Slide #3

The next two programs I am going to talk about are development programs, and hopefully we will also be able to come up with some answers that will complement the HH-53 Night/Adverse Weather Rescue Program. From the title, you can see that the advanced concepts referred to in the objective are controls and displays.

Within the area of controls, we have augmented the pitch axis by removing the high-frequency responses from the flight director system and fed them directly to the onboard flight control augmentation system. We are feeding to the flight director computer only the long-term responses for command presentation on the ADI.

For displays, we have a 3-cue flight director system. On the ADI we have a rising pad and a flight path angle tape as well as standard glide slope and localizer information. We also have a low airspeed system on board where the pilot has a remote slue capability. By this I mean, if he is flying at 60 knots and wants to change his velocity, say, to 80, he can slue the command bug on the indicator to 80 knots and will then get pitch and collective commands to achieve this new velocity.

For guidance we have on board a STATE system, which stands for Simplified Tactical Approach Terminal Equipment, and what it is, is a kind of remote ILS system, but it also provides range and range rate. We have plans to put in a doppler which will complement the flight director system with drift angle.

With respect to pilot techniques, what we are looking for is how do we best utilize the above elements for things like steep approaches to an ILS capture. To date, a lot of this has been simulation work. So far we feel we need the pilot in the pitch axis loop, we need a blend of the man plus some automatics. The yaw axis we feel has to be automatic, and the roll axis can be a manual (pilot) task.

We've demonstrated precise flight path angle and velocity control and the first successful flight test of the J-Tec low airspeed sensor was flown on our CH-3E. We got accurate readings on the sensor down to approximately 6 knots, ±1 knot, and if we would possibly revise the location, we could get better accuracy at even lower airspeeds. What we are doing now, is looking at steep approach angles. We've looked at angles up to 15 degrees and our ultimate goal is to see just what the limits are.

The future holds precise lateral control. We expect to achieve this by incorporation of the drift angle into the flight director system that I mentioned a minute ago. We want to put in a series/parallel servo arrangement into the yaw axis for automatic heading hold and turn coordination, and through a blend of pilot and automatics in the collective axis, we are going to stabilize the flight path angle or rate of descent.

Slide #4

We have heard a lot of talk this morning about workload during IFR flying. This program is primarily an investigation of handling qualities and workload during IFR work.

On board we have what we call a 4-axis pilot assist system. It consists of a parallel servo in each axis operated through force sensors in each control input device complemented by a radar altimeter and again, the J-Tec low airspeed sensor and the system is a doppler system.

I flew this machine last week on a pretty gusty day. It was 20 knots gusting to 30 and I was kind of amazed. It did a nice job. The aircraft would perform. I am going to refer over here now to where the modes are listed. The aircraft in the collective axis will hold altitude or altitude rate. It's mechanized so that when the rate of climb, or change in rate, is less than 90 feet a minute, it will hold an altitude in ±5 feet. If the rate of change is greater than 90 feet a minute, it will hold 500 feet a minute. In a pitch axis, we have, of course, the altitude and velocity hold mode, and on this particularly gusty day that I mentioned, we were doing 360-degree turns with 30 degrees of bank angle and this was a hands-off situation once established – and the aircraft would do it.

For data sensor integration we are looking at things like where do you switch from baro alt to radar alt with respect to these sensors talking to the PAS. We are also looking for a cross-over point between ground speed information from the doppler versus the low airspeed sensor.

For the human factors investigations we plan to fly seven subject pilots. We've so far flown three and expect this phase to be done in approximately six weeks.

The future tasks listed here are not firm, but if we could get some funds, we'd like to put a series servo in the yaw axis, because with just a parallel servo, those pedals are very busy and it's uncomfortable for the pilot – it's fatiguing for the pilot; let's put it that way.

The ground aids study would be done upon the completion of the human factors work, and what we are looking for there is to investigate and explore IFR approaches to a hover.

Slide #5

The last program I will discuss is the Pilot Factors for Helicopters Program (PIFAX-H). The USAF Instrument Flight Center down at Randolph AFB, Texas, conducted a study of all pilots within the Air Force, and it revealed that with correct displays and controls, mission effectiveness during IFR conditions might be increased 75 percent. So we said, okay, if that is the case, let's take a look at it. What this program is out to do is to provide proof of concepts of recent advances in controls and displays, primarily from the H-3 and H-500 program. We're going to mechanize the flight director system very similar to what's in the H-3. We feel the yaw axis is the worst one in the Huey, so we are going to put in a series/parallel control augmentation system. It will be mechanized so that we'll have heading hold automatically below 20 knots and above 20 knots, we will have automatic turn coordination. We will have a collective assist that will be similar to what is in the H-500, which will give us an automatic altitude hold or altitude rate hold.

We are going to have a remote heading slue capability so that when the pilot wants to change his course, he can slew his course remotely from a switch on the cyclic. The bug on the HSI will slew accordingly, and he will get flight director commands to fly that new heading. We are going to have a radar altimeter which we feel we need for low-altitude work, a J-Tec low airspeed sensor, a flight path angle tape, and a revised panel. Now with respect to this panel, we in the Air Force feel that we are not going to get a new helicopter for our existing missions. We are going to get an inheritance from another one of the services. The last time this happened, we had just a little bit of trouble because we couldn't fit our avionics into the appropriate space and the panel layout was just not suitable to the Air Force mission. So we are going to take a very close look at panel arrangement in this program for possible future application.

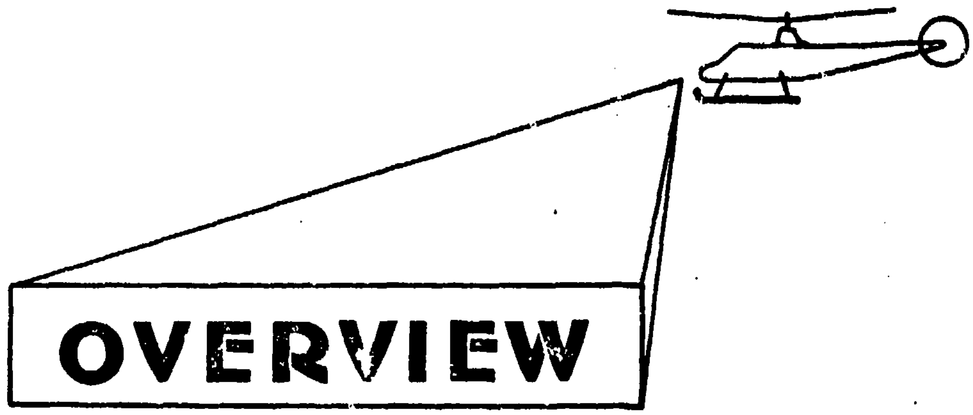
Where are we today? The first flight for equipment calibration is scheduled for Wednesday. Base-line flying is a data collection type of flying. We are going to take subject pilots and put them in an instrumented airplane; instrumented for attitude and pilot activity. We are going to run them through a series of upper-air maneuvers and document how well the pilot does these particular tasks. And later on in the program, we are going to take the elements that I mentioned and put them in one at a time, and we'll evaluate just how well the pilot can do this particular task better as the result of each improvement with respect to the data we collected from base-line flying. We feel that we are probably going to have to fly base line through about June, because we want to make sure we have good data to refer back to.

We are currently in the process now of synthesizing the various elements in order to get them installed in two TH-1F's.

As just mentioned, we are going to validate the functional elements, incrementally, to show the degree of improvement, and once we do that, we are going to provide the aircraft to the using Commands within the Air Force and we are going to say, "Okay, here it is, go fly it. If you don't want to look at the SAS, for example, turn it off. But if you think you might need one, it will be there for you to look at." We are going to have operational pilots flying this aircraft with respect to their own particular operational missions.

In closing, I'd like to thank AVSCOM for inviting the Air Force Flight Dynamics Laboratory, and I would like to offer our cooperation to any and all of the other agencies here today.

What you have heard with respect as to what the Air Force is doing is as much as I know, is as much as I could find out, and I don't want any of my remarks to be construed as cfficial Air Force policy.



USAF HELICOPTER INSTRUMENT FLIGHT PROJECTS

SLIDE 1.

HH-53 NIGHT/ADVERSE WEATHER RESCUE CAPABILITY PROGRAM

OBJECTIVE:

TO PROVIDE LOW LEVEL, NIGHT, ADVERSE WEATHER RESCUE CAPABILITY

ELEMENTS:

- FORWARD LOOKING RADAR
- NAVIGATION
- NIGHT VISION
- AUTO APPROACH / HOVER

RESULTS:

VFR NIGHT RESCUE SYSTEM DEPLOYED
SATISFACTORY TA / TF DEMONSTRATED

STATUS:

NEGOTIATING TO INTEGRATE & INSTALL EQUIPMENTS

FUTURE TASKS:

- FLIGHT TEST TO VERIFY TOTAL SYSTEM INTEGRATION
- DEVELOPMENT OF PERFORMANCE SPECS
- FLEET RETROFIT

SLIDE 2.

CH-3E V/STOL IFR CONTROL/DISPLAY TECHNOLOGY PROGRAM

OBJECTIVE:

EVALUATE AND INTEGRATE ADVANCED CONCEPTS TO PERFORM V/STOL MISSION TASKS IN ADVERSE WEATHER CONDITIONS

ELEMENTS:

- CONTROLS & CONTROL SYSTEMS
- DISPLAYS
- GUIDANCE
- PILOT TECHNIQUES

RESULTS:

- OPTIMUM MIX OF MANUAL / AUTO CONTROL
- PRECISE FLT PATH ANGLE AND VELOCITY CONTROL
- LOW AIRSPEED SENSOR DEVELOPMENT

STATUS:

CURRENTLY FLYING TO INVESTIGATE FLIGHT DIRECTOR STEEP APPROACH CAPABILITY

FUTURE TASKS:

- PRECISE LATERAL CONTROL
- AUTO YAW AXIS
- AUTO FLT PATH ANGLE CONTROL

SLIDE 3.

H-500 HELICOPTER—V/STOL
EXPLORATORY DEVELOPMENT VEHICLE

OBJECTIVE:

FLIGHT RESEARCH TO DETERMINE DEGREE OF IMPROVEMENT IN HANDLING QUALITIES AND PILOT WORKLOAD REDUCTION DURING IFR FLYING

ELEMENTS:

- 4 AXIS PILOT ASSIST SYSTEM (P.A.S.)
- LOW AIRSPEED SENSOR
- DOPPLER

RESULTS:

- 4 AXIS STABILIZATION ACHIEVED
- FLT TEST RESULTS MATCHED ANALYTICAL DATA
- P.A.S. MODES DEMONSTRATED

ALT. HOLD	HEADING HOLD
ATTITUDE HOLD	RATE OF DESCENT
VELOCITY HOLD	AUTO HOVER

STATUS:

- DATA SENSOR INTEGRATION INTO THE P.A.S.
- HUMAN FACTOR STUDIES OF IFR PILOT WORKLOAD

FUTURE TASKS:

- YAW AXIS MODIFICATION TO INCLUDE SERIES SERVO
- INVESTIGATION OF GROUND AIDS FOR IFR APPROACH AND HOVER

SLIDE 4.

TH-IF PILOT CONTROL DISPLAY FACTORS(PIFAX-H) PROGRAM FOR MILITARY HELICOPTERS

OBJECTIVE:

IMPROVE THE POTENTIAL OF THE HELICOPTER IN THE MILITARY MISSION THRU INCREASED INSTRUMENT FLIGHT CAPABILITIES

ELEMENTS:

- FLT DIRECTOR SYSTEM
- YAW SAS
- COLLECTIVE ASSIST
- DISPLAYS

RESULTS:

BASELINE FLYING COMMENCED JAN 73

STATUS:

- BASELINE FLYING TO CONTINUE THRU JUN 73
- CRITERIA FOR SYNTHESIS OF FUNCTIONAL ELEMENTS ESTABLISHED

FUTURE TASKS:

- VALIDATE FUNCTIONAL ELEMENTS
- DEMONSTRATE INCREASED INSTRUMENT FLIGHT CAPABILITIES

SLIDE 5.

COLONEL GEARY: John, I'm beginning to realize why you are here as one of the panel members – because nobody else is here to pick on; besides, you represent the operators and the rest of us are sort of problem solvers, I guess. Another problem solver here, whom we have next, is Mr. John Garren. John has been working at Langley for the last 13 years in the study of helicopter handling qualities requirements and terminal area IFR operations, and I guess, during the 13 years, one of the most recent significant milestones as the result of his efforts was reached last year when he accomplished a full automatic approach and vertical landing of a helicopter to a designated spot on the ground. That is quite an achievement. John is currently in the Control Guidance Section of the Low Speed Aircraft Division at the Langley Research Center.

JOHN F. GARREN
LANGLEY RESEARCH CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

May I have the first slide, please. (slide 1)

I have the same tale of woe as Chip, about the time, but I'll race through my slides as quickly as I can. What I hope to accomplish in the next few minutes is to acquaint you with the fact that we do have a strong on-going program at Langley that I think is quite responsive to many of the problems that have been outlined today. This program was developed over the past year or so and is a follow-on of the work that we have been doing for about the past twenty years in helicopter handling qualities work. We call this VTOL approach and landing technology program by the acronym VAULT.

I expect this program is going to be all the more responsive to the Army's requirements in the next few months; we are trying to develop a joint effort with the Army at the present time. I will present the objectives of this work, the scope of the program, and try to describe some of our facilities.

Next slide, please. (slide 2)

Our objective is to develop a technology base for VTOL terminal area operations for the 1980's. The performance requirements that are associated with this kind of objective, based on our analysis of the problem, are going to require a near zero-zero IFR capability, the ability to fly approaches that are optimized with respect to noise, fuel, and ride qualities, and to be able to accomplish this while operating at low altitudes. The system features that we believe are going to be required to achieve this kind of performance are as follows: We are going to have to rely to a large extent on automation, and one of the things that our program is trying to determine is how much automation, what kind, and where it should be used. We believe there is going to be high reliance placed on high-gain manual control modes – the type of systems that are able to decouple the aircraft's responses and make it insensitive to external disturbances and give the pilot an invariant response for all vehicle configurations. Another feature of the systems, we believe, are going to be CRT displays. (I would like to digress a moment at this time. I feel like I have been talking to a Flight Director Admiration Society. We accomplished quite a bit using the 3-cue flight director over the past three or four years, but we have observed quite serious problems with the flight director concept for the kind of work I'm talking about here. We believe these problems are quite fundamental; we see the electronic display as the type of display that is going to let us put it all together and get the information integrated in a form where the pilot can not only use it, but also have a high level of confidence in what is going on.) There is a need to develop a low-cost inertial measuring system, and get the kind of signal quality we feel is needed in the display/control concepts that are envisioned. There is also a need to provide hemispheric landing guidance coverage.

Next slide. (slide 3)

I won't go through this slide in detail. Its purpose is to provide some of the justification for the work we are doing. What we have done on the basis of different items that pertain to VTOL operation, such as approach angle, for example, is to compare the VTOL against the STOL. Assuming the STOL objectives are achieved, this slide indicates that there is still a long way to go before we have developed the technology needed for VTOL. We have indicated here in the areas of navigation, control, display, and operating techniques, the technology areas that are impacted by these differences.

Next slide. (slide 4)

This slide indicates the scope of our program. It's funded out of three different divisions in Headquarters so we have split it up this way so each division can see what they are getting for their support. In the handling qualities area, we are concerned primarily with the development of display logic, format, symbology, looking at advanced control concepts, cockpit layouts, pilot interaction schemes, and interface with automatic systems. Under the operating techniques area, we are concerned with the integration of VTOL with other systems like the ATC, the microwave landing system, and how we utilize the VTOL's unique capability to the best advantage. In the avionics technology area, we are trying to define technology to permit low-altitude navigation, hemispheric landing guidance, techniques for designing of these advanced control systems, etc.

Next slide. (slide 5)

This is a picture of our CH-46C research helicopter that was provided to Langley by the Army, about eleven years ago. We have been using it since then in handling qualities work; in the last four years, in a concentrated investigation of terminal area research problems. Some of the features are as follows: it has a fly-by-wire system in the four controlled degrees of freedom, analog and digital computational capability, and inertial smoothing system. The right-hand cockpit is configured as a research cockpit; there is a ground-to-air data link, a long flight endurance, safety pilot, and large research payload to facilitate our studies. Incidentally, the CH-46 is the vehicle that was used in the automatic landing research that was mentioned.

Next slide, please. (slide 6)

This is a picture of the SH-3 helicopter which we are using to explore advanced display concepts. What you see here is a downward-looking TV camera and a forward-looking camera.

Next slide, please. (slide 7)

This next slide shows some of the systems that are installed in the SH-3 aircraft, and I'll use it to discuss some of our research plans for this aircraft. There is a CRT display in the cockpit. We have on board equipment that allows us to split the image from the downward and forward looking cameras and mix them in any desired proportion. We are not interested in closed-circuit television, per se, but we are using it to synthesize advanced type sensors and display concepts; looking forward to the time when there will be sensors that can perhaps look through the fog, or where we have computer capability that will let us synthesize displays. As part of this effort, we will actually be evaluating some of the sensors like forward looking infrared (FLIR), and we will be using computer-generated symbology to augment the real world scenes that we get from the TV cameras and FLIR.

Next slide. (slide 8)

One of our major vehicle plans for the future is based on the CH-47 helicopter, which we hope to obtain in a joint program with the Army. Hopefully, it would come from the "TAGS" program. What we have done here is to sketch some of our longer range plans for that vehicle, where we would add engines to provide a fifth controlled degree of freedom. With such a vehicle we should be able to synthesize any type of VTOL or compound helicopter, and develop hovering techniques, handling qualities, and displays for such a configuration.

Next slide. (slide 9)

This next slide illustrates some of the research facilities we have available and how we use them in our programs. Shown here is the tracking radar system that provides precise position information to the aircraft and also over to this van, in which will be housed a display generation system. We have already procured the system but it is not located at Wallops yet. This computer-generated display facility will receive information from the aircraft and from the guidance system, put the picture together in a TV format, and send it up to the aircraft over a TV link. We also have the capability of using the rather vast array of computers at Langley to synthesize an ATC traffic environment, and subject our research vehicle to that environment, and vice versa.

Next slide. (slide 10)

This is a schedule of some of our work – I will describe some of the highlights and milestones. We attempted to depict here about three different phases: the current program with our CH-46, the CH-46 with an advanced display capability which we are in the process of procuring, and the work we have planned to do in the CH-47. The milestones are keyed to those items down here. The first automatic straight-in approach, which we accomplished last year. In a couple or so months, we should be able to demonstrate an automatic curved approach – curved to a vertical plane. Just last week, we were able to perform manual approaches, curved in the vertical plane. The systems that we were using provided us with an attitude command in pitch and roll from a high-gain system, a pilot-selectable heading hold/turn following mode in yaw, and a velocity command system for the vertical degree of freedom. In addition to this, we were using the 3-cue flight director to provide commands for power, pitch attitude, and bank angle. The advanced computer capability shown here on the schedule will allow us to fly approaches that are curved in three dimensions, both vertically and horizontally. We should have our advanced display in full swing by this time, and thus be able to incorporate the integrated display that we think is going to be necessary to achieve this feat.

This work will continue with the CH-47 in order to develop a 4D control capability, where we are flying as a function of time as well as trying to control our position in space. This point here being where we hope to modify the aircraft to a fifth control degree of freedom and essentially repeat these steps for different VTOL configurations.

VTOL

APPROACH and

LANDING

TECHNOLOGY

DISCUSSION TOPICS

- OBJECTIVE
- PROGRAM SCOPE
- RESEARCH FACILITIES
- SCHEDULE

SLIDE 1.

VALT PROGRAM OBJECTIVE

- OBJECTIVE: TO DEVELOP TECHNOLOGY BASE FOR VTOL TERMINAL AREA OPERATIONS FOR THE 1980's

- PERFORMANCE REQUIREMENTS:
  - NEAR ZERO-ZERO IFR CAPABILITY
  - OPTIMAL TRAJECTORIES (NOISE, FUEL, RIDE QUALITIES)
  - LOW ALTITUDE NAVIGATION

- SYSTEM FEATURES:
  - HIGH DEGREE OF AUTOMATION
  - HIGH-GAIN MANUAL CONTROL MODES
  - ADVANCED DISPLAYS BASED ON CRT TECHNOLOGY
  - REASONABLY LOW COST RADIO/INERTIAL NAVIGATION
  - HEMISPHERIC LANDING GUIDANCE COVERAGE

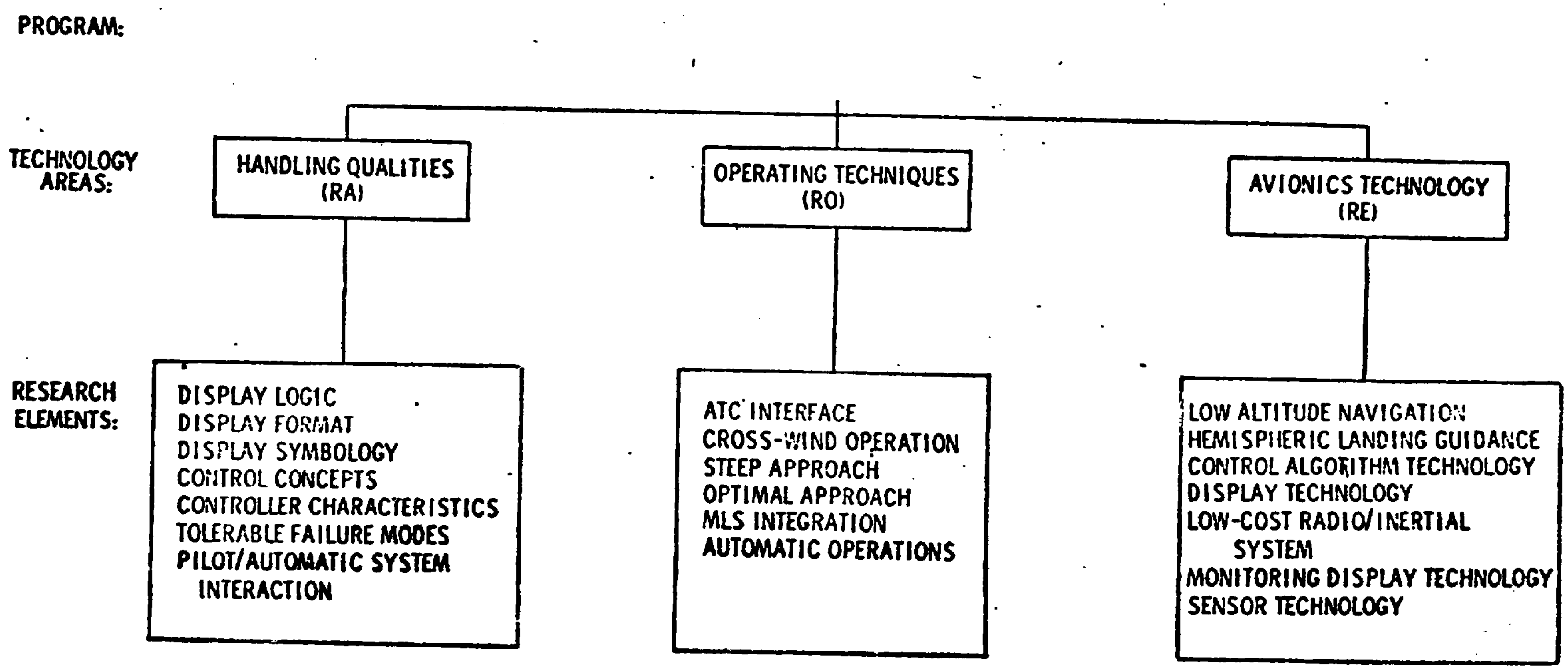
SLIDE 2.

ITEM	OPERATIONAL DIFFERENCES		TECHNOLOGY IMPACT			
	STOL	VTOL	NAVIGATION	CONTROL	DISPLAY	OPERATING TECH
Approach Angle	<9°	$\leq$90°	Elevation coverage	Automatic control	Look angle variation	Exploration required
Automatic Sys. Failure	Abort approach	Continue approach		Adv. manual	Adv. display	Manual takeover split axis
Runway	2 - 3000 ft	200 x 200 ft pad	Ground speed High accuracy 3-D	High precision and accuracy		
Terminal Location	Surburbs	City center	Low altitude navigation	Automatic control	Real-world cues	Optimal trajectories
Approach Constraints	Airspace, noise	Airspace, noise, fuel, obstructions	Algorithms/ optimum trajectories		Display content	ATC vehicle interface
Configuration Changes	Extension of current practice plus effects due to powered lift	Cross configuration and control function changes		Algorithm development Efficient computer usage	Complex monitoring task Display content	Cockpit controllers
Cross Wind Effects	Safety limitation	Operational proced. limitation	Azimuth coverage	Control law development	Look direction variable	Develop VTOL cross-wind techniques
Deceleration	Open-loop technique (air referenced)	Precised closed-loop control to zero speed & range	Precise range meas. High quality vel. signals	Transition from air to ground reference	Display content	Deceleration profiles

SLIDE 3.

COMPARISON OF VTOL AND STOL OPERATIONAL REQUIREMENTS

VALT DISCIPLINARY ORIENTATION



SLIDE 4.

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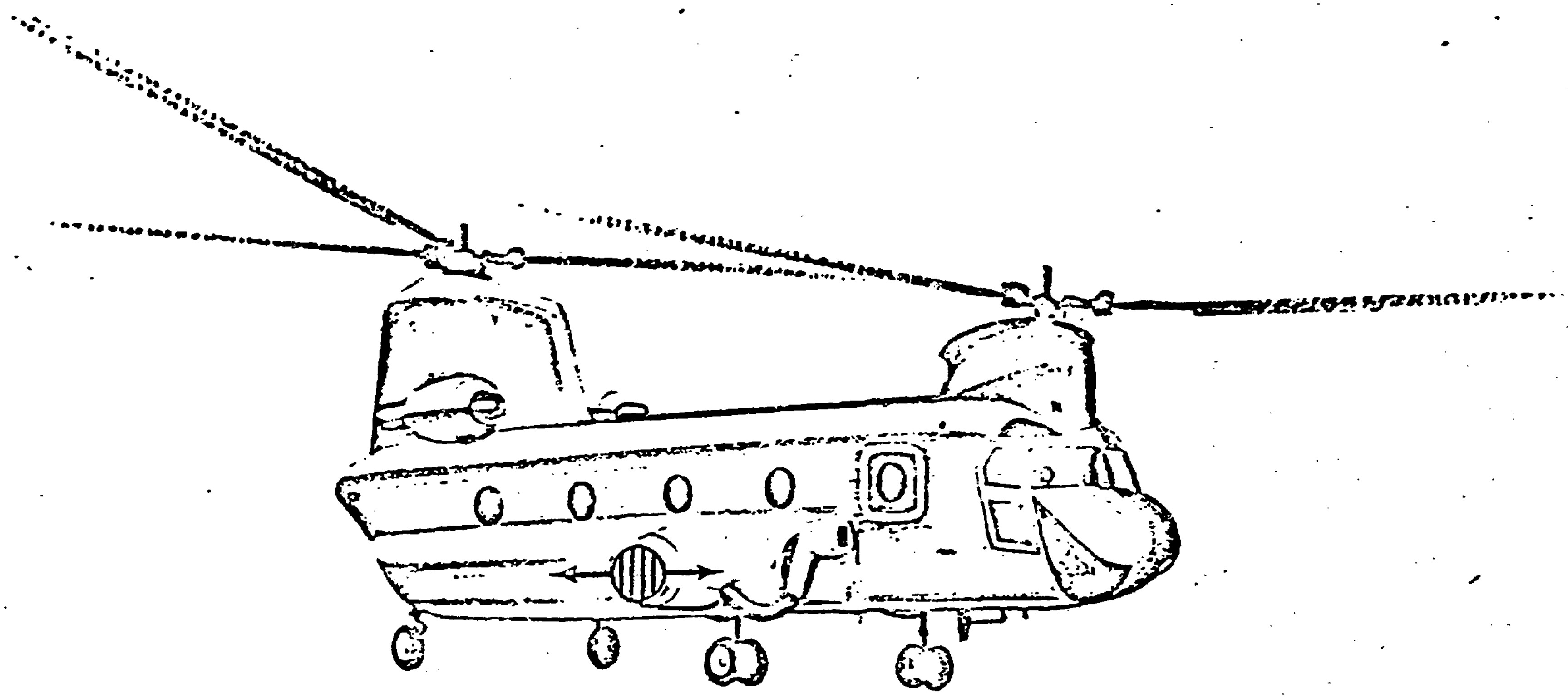
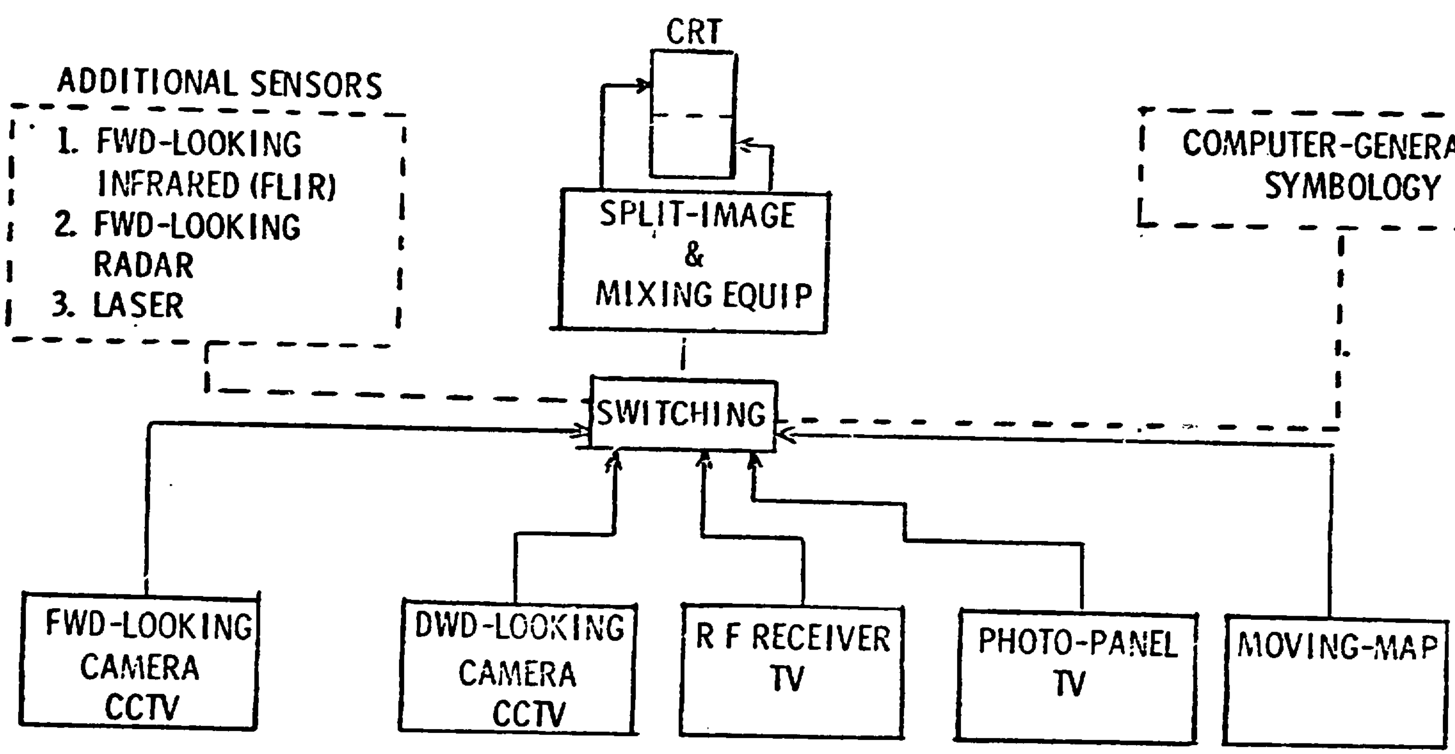
PROPOSED MODIFICATION TO CH-47 AIRCRAFT



SLIDE 7.

VTOL "REAL-WORLD" CUE DISPLAY PROGRAM

(SH-3A)



NASA LANGLEY RESEARCH CENTER

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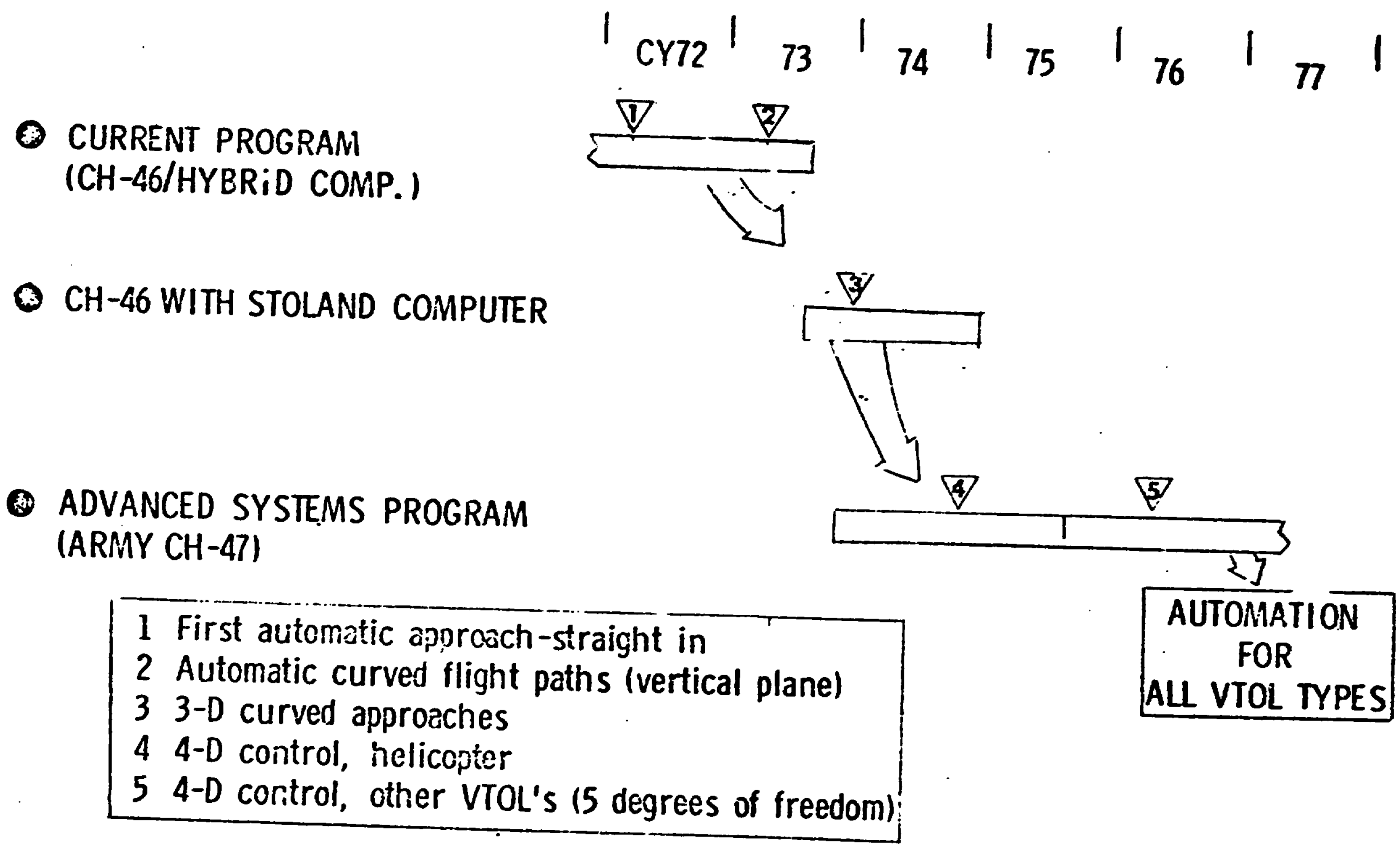
PROGRAM CONTINUATION



SLIDE 10.

COLONEL GEARY: So you see, the government elements we have represented here are exploring a great variety of current problem solving, and to put the clinch on this and let us know what our regulating agency is doing within the government, we have the pleasure of having Dennis Tuck from the Washington FAA agency, who is Director of Flight Test Operations there, to tell us what they're doing in their FAA thing.

DENNIS TUCK
FLIGHT TEST BRANCH, AIRCRAFT ENGINEERING DIVISION
FEDERAL AVIATION AGENCY

Thank you. I was going to start out by saying, "We may be last, but we certainly don't think we are least."

I was just thinking, listening to Joe Mashman's talk, perhaps I should have followed Joe Mashman, because when he described the operator's problem I believe we're the problem.

We've been involved in several IFR certification programs, starting in the late 50's. The first was a small utility 4-place helicopter. Initially, when we were asked to come up with a set of minimum standards for certificating this helicopter for instrument flight, we felt that basic bare helicopter handling qualities for most of that generation of aircraft were unsatisfactory for instrument flying and they should fly something like a fixed wing airplane that meets the fixed wing stability requirements or should have something equivalent to the ease of flying a fixed wing airplane. I don't think in the years that have followed that we have changed much in our approach to the problem of IFR flying of helicopters. I think we still feel that helicopters should have something like the airplane's stability requirements, or at least be as easy to fly as a stable airplane, either on a comparison basis or equivalent basis. We established a set of rules for the first IFR helicopter in the late 50's; they have gone through a number of changes since then, but basically they are not too much different. The requirements that we have now are contained in a project that we are working on for a proposed rule making. Essentially, the rules that we are developing are the same for both the small utility and the large transport helicopter, insofar as they speak to handling qualities. We don't see a basic difference in the ability to fly an airplane easily for a small airplane or a transport. Actually, our fixed wing rules for small airplane and large airplane handling qualities aren't too much different either. Our requirements that we have in a rule making project are actually the requirements that we are applying in what we call interim standards to the current generation aircraft that are being currently evaluated for IFR certification; namely, the Bell 212, twin-turbine Bell helicopter and the Sikorsky S58T, which is also a twin-turbine modification of the H-34. We speak to in our requirement the same things that 8501 speaks to in terms of static and dynamic stability, but we don't define quantitatively the same levels of handling qualities that the military specification does. I think that historically we and many others have looked at 8501 and 8785 as being design objectives. Our job is a little bit different than the military procurement, in that we are looking for acceptable standards in terms of safety alone, so we don't feel that we can use the military specification handling qualities directly. We lean to a large degree on some very general requirements that speak to the same subject and issues, but we depend largely on a qualitative assessment by the pilot. It's largely a pilot judgment item, and I think for the near future, based on our work with a number of agencies that are experts in the handling qualities field, that it will remain a qualitative assessment primarily, with some minimum guidelines in the interim to follow.

In the 212 program, we followed what we had done in the past on some of the other aircraft, the others being the Langley utility helicopter and the Sikorsky S-61, which is the civilian equivalent of the H3 helicopter, Vertol's 107, a commercial equivalent of the CH-46, and then we looked at the basic requirements to see how it comes from the bare minimum that we could write down in terms of a requirement that we could rely on and then used more than one pilot in arriving at a conclusion that the aircraft is satisfactory for flight in instrument conditions. We don't allow reliance on crutches, although they are useful (*ie*, the flight directors). We require as a matter of policy that the basic aircraft have good handling qualities without credit for the use of aids such as flight directors. I am not knocking flight directors. I think they're great. I think there are many types of operations, both in airplanes and helicopters, where flight directors should be essential, once our requirements have been met by artificial stability augmentation. I don't think there are any current generation helicopters that would meet our concept of the minimum acceptable level without some augmentation. I don't think as a civil aircraft approval agency that we would be in a position to approve any of the existing helicopters with whatever crutches might be available today for IFR flying without some form of stabilization augmentation. In that regard, the different approaches to stability augmentation have provided some problems in defining handling qualities requirements. We don't have any basic minimum handling qualities standards that you can apply across the board to assessments. It is really a fly-by-wire system; even though you have a full time mechanical connection on a hydraulic actuator, you wind up, in many cases, with essentially a fly-by-wire system, and our old concepts of stability do not apply too well. We don't have anything to replace them with now, so in most systems we rely fairly heavily on a pilot analysis.

As to current problems, the one that I just mentioned is that the handling qualities are now met in most of the helicopters with an electronic stabilization system. We have some problems, and I guess the operators have expressed the same problems, that there are no helicopter airways and there are no helicopter approaches in the United States airway system. I think this is going to be essential. The helicopter utility in the United States is going to increase, especially for commercial operators. There are a number of ground equipment and airborne equipment that are available and could be used to develop such systems. I am thinking primarily of the microwave landing systems that are on the market today.

There are navigation systems that can be used on board for local navigation in metropolitan areas, in any area, as a matter of fact, but right now most of the helicopter IFR flying in this country is commercially done on fixed wing systems and fixed wing approaches. In my own experience, I did some flying in the Navy Reserve in ASW, and most of our approaches to the naval air stations and civilian air stations were done to airplane approach systems and approach procedures, and I don't think this increases the utility of the helicopter one bit. I think we need some special systems that are tailored for the helicopter. Another problem is icing protection. We require for basic IFR helicopter operation that the engine's inlets be protected from ice. So far, no one has approached with a helicopter or airframe and rotor deicing system or anti-icing system and asked for icing approval for flight into icing. We had one applicant for limited icing approval, but as in the requests for limited IFR approvals, these become very difficult to control. I think it may be of interest to mention one of the problems we ran into at looking at a way of approving flight and icing for single-rotor helicopters. If the rotor or rotor components shed ice – large ice particles – how do you protect the tail rotor from damage, or other parts essential to safe flight? Many of the single-rotor helicopters offer the possibility of slinging large chunks of ice into the tail rotor, and this could have disastrous results.

One other area that I might mention at this point is that on helicopters that had been approved for IFR flight, including the small utility helicopter, we have required two IFR-qualified pilots on board. We have been asked at this point by the HAA and by Bell to consider some way of approaching IFR flight by one pilot. I don't think that we would consider lowering the helicopter handling qualities standard, but we are studying the need for two pilots at this time, and whether there are any compensating features that would make a second pilot unnecessary or really not as essential to the safety of flight. I think we would welcome the opportunity to discuss the subject and work with anyone that might be interested in this same area. In the future, I think for our near future, we would be very happy to work with anyone that is interested in IFR requirements, because we still are looking for better ways to go, as I am sure everyone here is, or you wouldn't be here.

COLONEL GEARY: I'm not going to give Joe a chance to rebut that. I noticed that Bob Richardson in the audience didn't miss a word that was said. We all know that Dennis has you outnumbered because he has got several of his cohorts from the FAA headquarters in Washington. It becomes pretty obvious in this short session we have had here, before you all get tired of sitting, that really we tried to cover a hell of a lot in a short period of time, and this is just an opener on a large encyclopedia of efforts and tasks that are being attacked and being performed by the government. Tomorrow, we will give industry a chance to tell us what they're doing and what they can do to help us solve these problems.

SESSION II

PANEL 2

HELICOPTER INSTRUMENT FLYING QUALITIES REQUIREMENTS

MODERATOR

MR. JAMES S. HAYDEN
USAASTA

PANELISTS

MR. NEAL DONALDSON, AVSCOM

MR. ROBERT TAPSCOTT, NASA

MR. RONALD ERHART, BELL

MAJ PAUL J. BALFE, USAF

MR. A. H. HUTTO, BOEING-VERTOL

MR. ROBERT S. BUFFUM, NATC

MR. DONALD R. SEGNER, LOCKHEED

PHOTO 1. SESSION II. PANEL 2.

PHOTO 2. SESSION II. PANEL 2.

INTRODUCTION OF PANEL
HELICOPTER INSTRUMENT FLYING QUALITIES REQUIREMENTS

JAMES S. HAYDEN
TECHNICAL DIRECTOR
US ARMY AVIATION SYSTEMS TEST ACTIVITY

We ask that you hold your comments and questions until all the panelists have talked. We would like then to encourage an interactive discussion.

In the previous reports that you heard this morning, several anomalies were revealed; there were situations where the helicopters tested met the specifications but were unsatisfactory; also the converse, we saw, where it didn't meet the specification but the characteristics were considered completely satisfactory.

There are several specifications that we have to consider in the business: the new Air Force specs, H-8501A, and the H-8501B draft, and with that I would like to introduce Mr. Neal Donaldson, who has been coordinating the efforts at AVSCOM in coming up with a new 8501B. Neal has a Bachelor's in aeronautical engineering and he was a successful flight test engineer out here with us at ASTA for three years, and is now at the Flight Standards Office at AVSCOM.

MR NEAL DONALDSON
US ARMY AVIATION SYSTEMS COMMAND

Several speakers have already identified the relative obsolescence of our current flying qualities specification. Because MIL-H-8501A has not been updated for almost twelve years, a specification revision incorporating recent helicopter experience was deemed desirable. A joint Army/Navy effort began in late 1971 to develop this specification and a supporting document which would be similar in format to MIL-F-8785B. This specification will be based on current and past helicopter flight test programs and the experience gained through MIL-H-8501A specification compliance evaluations. The proposed MIL-H-8501B will be more of a design specification than its predecessor had been. Moreover, the proposed specification will be used in a more flexible sense in procurement actions and new designs.

There are three categories of instrument flight capability to be used within the proposed MIL-H-8501B. They are minimal capability, nominal capability, and maximum capability. These designations will provide a clear statement of three logical levels of operational instrument flight capability. This definition will allow the designer and the procuring activity to visualize the tradeoff in system complexity, cost constraints, and other considerations. In addition, the three designations will prevent the overstatement of requirements where they are not needed.

The proposed specification also adopts the concepts of flight envelopes in order to separate the mission-essential flying qualities requirements from those which might be deemed desirable but could involve added system complexity, added aircraft weight, or compromise of characteristics elsewhere within the operational envelope. It is obvious from the ASTA presentations that the specification must be more oriented toward mission tasks. It has been pointed out that satisfaction of any given set of flying qualities requirements will not necessarily assure adequate instrument flight capability. The combined effects of all stability and control characteristics may be such that the pilot cannot perform the IFR mission without excessive workload or risk to aircraft and crew. By the same token, a helicopter can be in noncompliance with specification requirements and still be a satisfactory aircraft for instrument flight.

One of the concepts used during current Army procurements, such as the recent UTTAS procurement, was the adoption of large portions of the existing military specification and the revision of other portions, with additional requirements added over and above the basic specification. In this manner, recent experience with instrument flight evaluations, such as those described here today, could be incorporated into a continually adaptive specification.

In summary, let me state that the new military specification will be an attempt to more readily accommodate the specific criteria requisite to IFR missions. We will draw upon the information discussed previously today and also on the information yet to be discussed by this panel.

MR. HAYDEN: Our next panelist hardly needs any introduction. Kenny Amer contributed tremendously to the flying qualities knowledge and interpretation in the 40's; Bob Tapscott picked it up in the 50's, and supplied many of the numbers that form the basis for the H-8501 and H-8501A revisions. He presently is head of the Flight Research Branch of the Low Speed Aircraft Division at Langley. He is a World War II pilot.

MR ROBERT TAPSCOTT
NASA

I think a good deal that we have heard today and what we have just heard about the revision of the new specification brings a question to mind: What is the role of the specification, or what should it be? The early flight studies that were done for instrument flight of helicopters took place in the early 1950's, and at that time we came up with requirements for some stability augmentation, for some flight control system characteristics, and even flight directors, believe it or not, were tried back in those days. I remember one was called the Sperry Zero Reader and I believe it incorporated very much of what is now considered in the present flight director. These results were used in the drafting of the military specification H-8501A in the middle 50's, and these specifications, as you heard earlier this morning, do include some additional requirements for IFR. In the interest of time, I am not using any slides, but I did have one slide. I wanted to show the numerical values that were put in the specification – I pulled the slide out of the drawer where it had been laying for 15 years, and I think that brings up some kind of a point, because most of the discussion we have heard here this morning on the flight test of helicopters – most of the deficiencies of those machines are covered to some degree in 8501A. There are numbers there. I think that this tends to indicate that these numbers have not found their way into any design process, at least not on any extensive basis. The specification in the last decade and a half has become primarily a test and evaluation specification and it was originally intended as a design specification. So the use has sort of done a flip-flop and the basic purpose of the specification has not been realized. It has served, I think, a very useful need for the user agencies in documenting the characteristics of the aircraft and as a guide against which to evaluate them. I think the question that needs to be asked is "why has the specification not fulfilled the requirement as a design guide?" Also, I think it is possibly because that in the specification, at the time, we were not as advanced with system analysis capability as we are now and a great deal of information is in there in bits and pieces. I think the designer is now faced and has been faced all along with a systems requirement. He has to put the aircraft, the flight control system, and the task or mission all together in one whole new type of system and come up with a combination of all of these – that gives the performance of a system.

I wonder if maybe in the design of the new specification – maybe we need to have two specifications. One as a test and evaluation specification and another one for design guidance which would be more in the form of a performance specification. Give the designer the performance requirements, rather than tell him how to design – tell him what to design for and let him come up with the requirements.

I just saw one very nice example here today. We had the word redundancy used here this morning and I wonder if the speaker, I don't remember who it was now, really meant redundancy. I think he should be telling the designer he wants reliability, but there had been an inherent extrapolation of his requirement of reliability into redundancy. Now, maybe redundancy means to him the same thing as reliability. I'm not sure that it does to a number of designers, and I wonder if this has not been characteristic of a lot of the terminology, whether we are talking about control power, angular velocity damping, and all of the things we saw listed on Dick Lewis' slide today. I think those are all bits and pieces that need to be put together in a systems approach and give the designer a performance specification to design to, rather than numbers and requirements for individual components of the system.

MR. HAYDEN: Bob, I remember some of the discussion that went on when the 8501A was being coordinated with industry. We were sitting on separate sides of the table at that time.

Our next speaker, Ron Erhart, has a very diverse background. He has a Bachelor's in mechanical engineering. He was an Air Force pilot for five and a quarter years, with both jet pilot and helicopter time He has been with Bell for nine years as an experimental test pilot and is their IFR project pilot.

MR RONALD ERHART
BELL HELICOPTER COMPANY

My comments will be very brief.

We have just completed the two-pilot certification of our Bell 212 under IFR requirements and some of the rules that we had to meet in this and some of the inadequacies of 8501A were brought out very strongly when we went to a stability augmentation system. A stability and control augmentation system, such as in the 212 gives you a control characteristic that is tailored by electronics. When we test these systems against MIL-8501A and the FAA rules, the SCAS covers up such things as basic dihedral effect. For instance, if you put in pedal, the SCAS holds you level so you don't roll. It indicates a neutral dihedral stability. My main comments are to raise some questions to be considered in the writing of 8501B – what you would do and how you would test stability systems to meet these requirements.

MR. HAYDEN: I hope you have recovered from going through an FAA certification. I went through one of those once.

Our next panelist, Paul Balfe, is almost indigenous to the Edwards area. He has a Bachelor's degree in math and physics. He has a Master's from USC. He attended the Test Pilot School here at Edwards in a class immediately preceding the one that Colonel Geary went through. He has spent twelve years on the base, flight testing helicopters. So with that, I would like to introduce Major Paul Balfe.

MAJOR PAUL J. BALFE
AIR FORCE FLIGHT TEST CENTER

After listening to how the Navy operates their airplanes, it makes us look kind of backwards because we still fly our helicopters the same way we fly our fixed wings on instruments. Now the first breakthrough I think, on this is the airplane Chip Winter discussed, the night rescue H-53 or Pave Low, which I have been working on since January of 1970. The rest of the helicopters are operated either VFR or, if you're flying weather, you use standard fixed wing procedures.

This is because of two reasons: one that Mr Tuck mentioned, that there are no special helicopter techniques or approaches published, although the Air Force now is working on helicopter approaches to some airdromes. However, they are basically based on fixed wing criteria and approach techniques. The second reason is that our procedures are designed around the basic flying quality deficiencies of the aircraft we have.

One classic example of this is the H-1 series where we use climb speeds of 70, to 80, to 90 knots, rather than the best rate of climb speed for the aircraft, which is around 55 or 60, because the aircraft is longitudinally unstable at the best rate of climb speed. Also, to assist in giving the pilot a better margin of control, a low rate of climb is used. They recommend 750 feet a minute rather than the actual performance that the aircraft is capable of. In the H-53 series, which has a nice AFCS, and handles very well, we use an approach speed of 110 knots. The T-33, which I flew up to a couple of years ago, flies final at 120.

There is really not much advantage to flying a helicopter if you're going to go smoking around in the air and do instrument approaches at 110 knots. Now the reason for the 110 knots final is the aircraft flies very nicely there. It has good cruise economy so you can hold and do that sort of thing, and you keep out of the fixed wing people's way. So you can come into a place and you make an approach at a speed compatible with the jets, and the approach controllers like this very well. The biggest problem is on breakout at low altitudes of 200 or 100 feet. You break out, set up to land, but you're doing 110 knots and the aircraft isn't capable of landing at this speed. I flew with several different pilots that made hooded approaches and at 200 feet you say, "Okay, take the hood off and land." The next thing they do is to balloon the airplane up past the 200 feet to try to slow the thing down. I have tried it myself, and trying to get stopped and not exceed the 100-foot or 200-foot arbitrary ceiling above the ground is very difficult. It is a big helicopter and you like to keep it maybe 50 or 100 feet above the ground while decelerating because the tail is a long way back – I've never figured out where it is – just back there somewhere.

I did a test two years ago on the Sperry's three axis flight director system. They use a decelerating approach and you end up over the end of the runway 75 or 100 feet at about 50 knots. From this speed you can make a very nice slowdown and landing. It takes very little distance and is using the aircraft's capability.

I think to really use helicopters like Mr Tuck said, we're going to have to get away from fixed wing techniques and on many of the aircraft improve the stability in the low-speed area. I think you want to do instrument approaches at 40 to 50 knots, so if you do breakout at 100 feet, you're essentially set up on what the man sees on a normal visual approach. He is set up to where he can complete a normal approach and land the aircraft.

MR. HAYDEN: Thank you, Paul. We're constantly beset with practical problems and conflicts with our fixed wing brothers.

Our next speaker this afternoon has a Bachelor's degree in engineering from Clemson. He was an Army aviator, both a fixed wing and helicopter flight instructor at Fort Rucker. He has been with The Boeing Company for the past thirteen years and has participated in many projects. He was project pilot on the Vertol 107 Model 2 certification for Category A (that's the procedure where you go vertically off the Pan Am Building), and he also has been project pilot on the CH-47B and C and is presently assigned as project pilot on the heavy lift helicopter.

A. J. HUTTO

BOEING-VERTOL

Our experience in improving flying qualities dates back to the HUP and H-21 and has continued through the Boeing 107, CH-46, and Chinook (CH-47). We were dealing with aircraft that exhibited unstable to neutral inherent stability so we have been working with redundant stability augmentation systems since the late 50's.

Bob Tapscott hit the nail on the head when he described the approach to arriving at a total aircraft system developed for IFR operations. We get our pilots and engineers together and solicit customer pilot and engineering opinion to clearly define the mission requirement and the stability systems, special avionics equipment, and pilot displays required to ensure mission accomplishment.

Our current philosophy on stability and control is (1) to provide selected flight condition hold (airspeed, altitude, and heading) to relieve the pilot of the task of stabilizing the aircraft, and (2) to augment control response to optimize response to pilot control inputs.

This isn't, in our opinion, whitewashing the stability and control area; on the contrary, the pilot is freed from continuous control to keep the helicopter in the air and can confidently handle routine IFR operations with ample time to devote to navigation and mission tasks. This ensures a reasonable low-fatigue workload which enhances safety.

We have done quite a bit of total system development in the Vertol 347 and a couple of CH-47C aircraft, one of which was evaluated here at Edwards AFB. We've gotten very good response, as reflected by excellent pilot qualitative ratings.

Our experience with separate handling of stability and control augmentation reveals a significant shortcoming of MIL-H-8501A. A longitudinal stability test in accordance with MIL-H-8501A will reveal response to control, but not the much stronger speed hold characteristics provided for gust rejection. The Mil Spec should be updated to ensure adequate testing for state-of-the-art systems.

I heartily underscore the comments of Dennis Tuck and a number of others concerning IFR helicopter operating capability. We must accommodate a helicopter approach to a hover and pilot-in-the-loop hovering in night and actual weather conditions. Only after accomplishing this will we be able to support military and rescue operations around the clock in all weather conditions.

Concerning the emphasis given to flight directors at this conference, I strongly endorse the contribution of this display to safe, efficient, pilot-in-the-loop operation. My experience in flight simulation involving IFR approaches to an IFR hover has revealed a serious problem of misinterpretation of the horizontal command bar in hover.

In the approach, the pilot is mentally oriented to forward flight (vertical situation) and any flight director will greatly improve his performance. In the final transition of the approach into a hover, the pilot is mentally oriented to an earth reference (horizontal situation) and frequent misinterpretation and 180-degree out-of-phase longitudinal control inputs are common. A flight director for helicopter use must provide optimum cueing in the approach transition and hover.

In conclusion, our experience has indicated the need for providing a stable vehicle with good control characteristics. I would emphasize the need for on-helicopter development of tactical guidance systems and displays to extend the helicopter's VFR versatility into night and actual weather conditions.

MR. HAYDEN: We did test both the 347 and the CH-47 with the uprated control system.

Our next speaker, Bob Buffum of NATC, has degrees in both aeronautical and electrical engineering. He has eleven years experience, much of this in industry in control system design, and he is presently a control system specialist for Pax.

MR ROBERT S. BUFFUM
NAVAL AIR TEST CENTER

Commander Beck pretty well stated the Navy's position in his comments in the last panel, but I would like to say that the Navy's requirements in IFR flight have been met pretty much by going to an automatic control system of some type. We are now in the process of procuring an AFCS for the last operational helicopter in the Navy fleet that has an IFR requirement. All of our aircraft do have automatic flight control systems of some sort or another. Basically, we have asked for inherent stability in the aircraft to at least achieve an abort capability or else required redundancy in the automatic flight control system. Our use of flight directors that have been so heavily emphasized here today has been very minimal, mainly because the sensors that are required to feed us the data to drive some sort of display did not exist. Our system for instrument approaches is a GCA, where the guy on the ground tells you where you are. We have recently finished a program at Pax River where we flew 3-, 6- and 9-degree approaches under simulated IFR conditions to 300 feet and a quarter of a mile. We found that the augmented aircraft were far superior and the deceleration phase at the end did require, as we heard earlier, airspeeds somewhere under 110 knots, because at 9 degrees you just can't hack more than that. We were flying approaches at 6 degrees at about 70 knots with every aircraft we had and initiating the deceleration visual contact from a quarter of a mile on in. It was a pretty successful program. I think we learned a lot about what types of aircraft could do these things, but we didn't really look at it from a flying quality standpoint. We have a couple of programs right now at Pax River that are going to look at flying quality terminal area problems for IFR; the CL-84 that Don Beck is flying now has a head-up display in it. We are going to be looking at what is required in the tilt wing VTOL in the way of displays and requirements there. We also have a UH-1N that is heavily instrumented and has a very versatile flight control system in it. We are going to be looking, in the next year, at variance in flying qualities as well as variance in approach paths using the SPN 42 system and we hope to define (at least for the single-rotor medium or light helicopter – now we're talking about 10,000 pounds) what are the flying quality requirements in this terminal area. We also have the Naval Air Development Center starting a program to look at the sensor requirements, that we hope ultimately will give us some display capability for getting back to the destroyer, getting in at least close enough to the man to take over, and bring the aircraft aboard.

MR. HAYDEN: Now we are going to put some life in the panel. Our next speaker doesn't need an introduction either. Don went through Class 19 of the Test Pilot School and flew as a project test pilot at Pax from '57 to '61, at which time he joined Lockheed. He has been involved in almost every one of Lockheed's flight developments from that time on. He is a Past President of the Society of Experimental Test Pilots and is a Fellow. He is the winner of both the Kinchloe and Chanute awards.

MR DONALD R. SEGNER
LOCKHEED-CALIFORNIA COMPANY

I really don't have too much; everybody has covered the subject well so I will keep it down to 20 minutes.

In reference to Bob Tabscott's conversation, I would like to reemphasize one principal objective during the formulation of MIL-H-8501A. This specification was principally designed to set forth basic design parameters in order to obtain overall desired flying qualities. It was not intended to make every helicopter meet certain specifications. I think people should look back, and if you weren't around then, I will reiterate that during that period of time the aircraft procurement contract procedures were different than they are today. When a contract was awarded, there were additional detail specifications that set forth the exact flying quality requirements for the mission of that aircraft, so MIL-H-8501A was principally a design criteria specification. If you go too far in detail with overall Mil Specifications, you are not going to permit enough flexibility in design of an aircraft for a specific mission capability. There are just too many different mission categories coming up, so when I speak to the instrument flying quality requirements of an aircraft, I always try to relate to the primary mission of that aircraft.

You can have an all-weather aircraft, a heavy-weather aircraft, or an aircraft that has minimal instrument capability for flying enroute IFR. I feel that every rotary wing aircraft now days has the capability to some degree of flying on instruments enroute.

What are we talking about then, when we discuss the subject of rotary wing flying on instruments? In reference to the Army situation we have to get other target areas and we have to operate in a tactical area, but other questions are – are we a true transport carrier; will we carry supplies; are you a scout aircraft looking for target, or are you an attack helicopter that will require mission firing in the tactical area? Each one of these has defined and definite mission roles and, therefore, their flying qualities will differ somewhat. Other questions, of course, that pertain to the degree of sophistication are directly related to the amount of time the aircraft will be flying on instruments. Are you going to operate on instruments at all times, 20% of the time, or 10% of the time? You do not want to compromise the basic mission of the aircraft with respect to maneuverability, flying qualities, and sophistication, if the aircraft is only going to operate on instruments for a very limited period during its mission cycle; for example, the flying qualities of a cargo transport, and particularly a civilian aircraft are totally different from those of a fighter or scout aircraft where a high degree of maneuverability is required vs high degree of stability. We know that neutral stability is desired in certain regimes of flying for the high maneuverability case.

We also know this is a no-no in transport aircraft where a large portion of the mission is spent on instruments with approaches made to very low minimums.

We look at black boxes as a means of providing the desired flying qualities in rotary wing aircraft, and I agree with Mr Tuck's comments that the basic failings of the black box still apply to all types of aircraft, specifically the inherent aircraft flying quality should be safe. They should be such that if a black box fails, or the pilot encounters a hardover in autopilot or stability assist, he should be able to recover and maintain normal flight conditions. I do not mean to infer that he may be able to complete his full mission on instruments, but that the basic damping stability criteria (short period, long period phugoids) and static stability requirements are very important for aircraft with IFR mission requirements. In addition, for those missions that a high portion are instrument flying it has been found that specialized training and skills are required, and that certain pilots can adapt to IFR and night missions more easily than others.

Looking again at the Army mission, we fly in a totally different environment than with fixed wing aircraft. We stay very low and the window for error and recovery from error is very minimal; therefore, the time for reaction is a lot less and total error margin is smaller. For aircraft in this mission environment, flying qualities must be inherently good. I try to categorize the IFR flying levels into phases; one is a direct enroute instrument only, such as with commercial operators flying in noncongested areas. The other would be Continental United States flying under FAA regulations, and the last category would be tactical flying. Here again in the tactical situation, what is the mission of the aircraft? Some transport flying missions will be done with single aircraft, and in others it will be desired to fly in large formations. In some cases the terminal landing areas will be basically VFR for helicopters and others will require critical pinpoint terminal guidance and approach flying mission to the operating zone IFR. The terminal guidance phase of flying has had much work, but is still the more critical. The FAA has been working on this since the early 60's at Atlantic City, New Jersey. NASA Langley has done a lot of work, and so has Ames with respect to terminal guidance problems. It has been determined that you can fly helicopters on a typical fixed wing ILS/GCA 3 1/2 degree glide slope approach without much difficulty or sophistication. Now the Navy has a different and more hazardous type mission for the terminal approach, *ie*, transitioning to a hover; but unlike the Army, they do not have to worry about exact pinpoint accuracy since they do not have to come in a tightly defined point over the ground. It appears then that depending on the mission of the aircraft, the degree of instrumentation and the flying qualities, integrated displays, etc, must be determined from the mission of the aircraft. The biggest problem today, I feel, other than having the proper flying qualities, is in the field of information displayed so that the pilot can integrate his information, know exactly where he is, and land at a pinpoint destination IFR at night. We have tried a lot of approaches to this display system, but all are complex and costly and tend to degrade the primary mission of the aircraft when not in use.

We at Lockheed have had a few research programs flying IFR from takeoff to touchdown in the XH-51A. The scope of one program was to fly the entire

ASW mission without the addition of any automatic stabilization, altitude or heading hold systems. It was determined that the IFR tasks were not difficult and with training a pilot could have reasonable consistency in transitioning to hover and maintaining hover over an ASW ball for extended periods of time. However, we found, and as we all well know, the name of the game changes considerably in the slow airspeed and transition regime of flight. Once you are below 40 knots the instrument flying game is a different world. You must forget about everything you knew about physical sensor cues. Here scan pattern, display integration of information and time to react is extremely important. If the mission requires prolonged flight in this area, sophistication to some degree is required. If the mission does not require transition in hover or vertical descents, I feel that the expensive equipment now being anticipated can be diverted to more accurate navigation requirements.

So I say, yes, we should have good basic inherent flying qualities in rotary wing aircraft for instrument flying. If required, for the extremely slow speed, hover and vertical terminal guidance phases, you will need some additional systems augmentation, particularly the directional and altitude control phases. A failure of augmentation equipment cannot disorient you – you must know where you are at all times. If the mission requirements are such that total IFR flying is required under extreme conditions, a specific aircraft must be designed to complete that mission. A pilot must be able to maintain orientation at all times and relate to his VFR environment. I, therefore, lean towards the night vision FLIR approach that is coming about to assist in the more demanding IFR tactical mission concepts. Perhaps we might consider some variations of this equipment even for daytime IFR missions.

DISCUSSION FOLLOWING MR. HAYDEN'S PANEL

MR. HAYDEN: I want to comment on radar altimeters. The HAA had a very excellent conference in Las Vegas last week and I attended the IFR session and we are going to see a fantastic movie tonight after dinner as the result of our visit up there; but every operator that is going IFR now, to a man, won't go without that radar altimeter in his arrangement, as the Navy has said earlier.

At this point, I'd like to get some interactive discussion and Don brought up a good point about putting your requirements directly in the detail specification rather than blanket quoting of military specification requirements. I wonder, Charley, would you like to make a comment on that.

MR. CRAWFORD: Well, I think the Army is going more and more, Jim, to mission-oriented type flying quality requirements that do go into RFP as opposed to spec. There are two advantages to doing this. Every airplane is different. The second advantage is that it takes an Act of God to update a spec; anybody can change an RFP only with the help of a couple of Apostles.

MR. HAYDEN: Tell me how you do that, Chuck.

MR. CRAWFORD: I guess I basically agree with the point, on the other hand, to make sure that the homework is properly done – I know the requirements that you're talking about, you still need to keep the long-term schedule in mind, because that is where the homework is done, not in the preparation of the RFP; the RFP is a panic thing.

MR. HAYDEN: Do we have any questions or comments from any of our panelists? I'm sure there must be some.

JOHN DIETRICH OF SPERRY: When you look at something that we build like the 8501A or the 8501B, what percentile of pilot proficiency do you expect? Obviously, you can't say that 100 percent of the pilots that are going to fly the airplane are proficient, from their own admission of their own competence, if you will. My question is, when you go for a spec, just exactly what percent are you going to try to protect, is it 90 percent of those that are going to fly it? You can't take care of more than that all the time. Would you care to answer that?

MR. TAPSCOTT: Well, the microphone got put in front of me. My name is Leroy, too. I think there probably are different answers to your question here. If you're talking about the FAA, I think maybe someone from FAA would rather comment on this, but as a frequent passenger on FAA certified aircraft, I would hope their designing would be for the absolute minimum pilot in that respect. Now when you get into the military part of it, you can say, well, yes, a proficient pilot can do this kind of a job; he can land the aircraft; but this, I think, gets into some pretty complex cost effectiveness studies. I think it may not be reflected in one approach or ten approaches or a few dozen approaches, but when you think of a full operation over a period of ten years and about how many of these aircraft are going to be lost and have to be replaced because of some of these characteristics that may not be very overt in your test phases, then it may be more cost effective to go ahead and buy some of the equipment and put it in the aircraft.

MR. DIETRICH: On the other side of that is that you are penalizing 90 percent of those pilots by keeping them in the needle, ball, and airspeed stage because of the tremendous cost.

MR. TAPSCOTT: Again I say, the cost is relative and I think it's a cost effectiveness standpoint. We can take a thousand-hour pilot in that particular aircraft and if he happens to be in it eight and a half hours that day and didn't get time for lunch, he is not going to be very proficient, so he needs a little help, too. So how are you going to balance an aircraft for all these varied abilities of the pilot? It certainly is not an easy question, but I think it does bear quite a bit of tradeoff studies in what is really cost effective. Do you really save money on your initial investment, or do you realize over the long run something back on your investment.

CONFERENCE ATTENDEE: Another aspect is you mentioned the 200-hour pilot, that's just sent into it. If your airplane is bad enough, you can't send him, and you end up with a 300-hour pilot and you've paid for another 89 hours worth of training on this man to get him proficient enough to handle this aircraft, so from that aspect also, you have to consider it and 89 hours is maybe, what? 3 months training, maybe more than that?

MR. HAYDEN: Yes, now talking about crew proficiency, that gets expensive in the states. The state of New York safety outfit has two KingAirs and one 212. They have identical instrumentation, and they treat them both as being identical, no difference in airplane and helicopter. The pilot has to be a 2000-hour pilot with 200 hours of instrument, 200 hours of night, and 200 hours in type. That gets to be fairly expensive pilots. If it's an airline pilot, the copilot has got to be fully qualified and current on IFR. They have to take ground school; they take a flight check every six months; they have to have an ATP; they have to have an ATP physical every six months; they have ground school once a year, so it can get expensive.

CONFERENCE ATTENDEE: I think Don said something there, Jim, that is important. The IFR flying that has been done both in the Marine Corps and the Navy, and that's been extensive, particularly in the Navy, this ASW dipping is not fun or easy. It's always dual-piloted. I will say that we did have one program which was a research program done in the XH's, you will recall, where we went out and we were told by the Navy to find what you can do – what you can go with simplest to do a mission and do the ASW dipping. To the XH's, which had at that time and still do have all damping parameters except directionally, we added a doppler ground speed and a doppler drift. We added a very sensitive ADI and we added a radar altimeter, and they put me in a box and I flew after about a week's period of time transitioning, over 100 vertical takeoffs and landings totally dark, not to a terminal point, but guided in from a thing. The only thing that I had was a trim system for directional, radar altimeter and directional hold. Even after about six weeks of this and this included dipping – about 150 dippings where you go to the ball, which is an even harder task because you're flying an airplane with only a ball, doing all this manually. I found that I could for 60 percent of the time come, make the transition after learning the aircraft's characteristics, scheduling the power, the attitude, get into a hover provided I had ground speed and understood the drift parameters – turning versus drift. After I got into the hover and tried to hold it, I found that about 60 percent of the time that I would lose the aircraft either directionally or in altitude and here was the integration of the scan pattern, so just the stability parameters alone aren't enough. There are certain things you have to have that let you have the information, because the scan patterns in the slow-speed, terminal guidance area are so great that a pilot just by himself can't seem to comprehend these things. This is why I did a mission. If you get a single piloted Scout, you can't afford to put a lot of stuff in, so you can't expect him to go in zero-zero, but maybe he can go in a quarter of a mile and 50 feet, I don't know.

MR. SNODERLY: I'm John Snoderly, Naval Air Systems Command, and I'm the Navy half of the spec effort. You all know the Army half and I would like to direct a comment to Mr. Segner and I would like him to appreciate the fact we are considering classes of aircraft. We do know that transport aircraft and agile scout aircraft have different roles altogether or what's required on a mission. This is our goal.

MR. HAYDEN: That's great. I have one request which Bob tried to do in 8501A. If you do design a parameter, make sure they can design to it. I'm not talking about handling qualities, but other parameters, sometimes responses aren't there to damp.

CAPTAIN MC ELREATH: Yes, I am Captain Ken McElreath, Air Force Flight Dynamics Laboratory. At the Instrument Flight Center of the Air Force down at Randolph, which is where we probably do more instument flying than anybody in the Air Force, they use the TH-1F's, which are better than the UH-1's for instrument flying. They have at least the basic radio navigation plus dual installations, and the saving which we are going to realize in getting improved IFR capability in terms of handling qualities and displays, comes in the area, also, of this dual pilot. To those people down there the UH-1 is a single-pilot aircraft VFR. Not only are they unable to use the aircraft in many IFR conditions because of their low minimums or what have you, but every time they do go IFR, they must go with two pilots. They do this categorically because first of all, the primary pilot cannot divert his attention from his control panel long enough even to begin to look at approach plates; this comes in the stability characteristics of the aircraft; and secondly, he can't divert his attention from his instrument scan enough to look at an approach plate or what have you, so it comes in both areas, in stability and in the instrumentation. Now then, given better stability and instrumentation, how much are you going to save and how much cost effectiveness can you prove by getting rid of the other pilot that you have to carry along simply because you're going to go single pilot. These are a lot of training dollars.

MR. HAYDEN: Yes. Anybody like to comment?

MR. BUFFUM: I'll comment. I think right now, as I said earlier, the Navy has gone to AFCS in every aircraft that we are using in the fleet today that has an IFR requirement. We are still going to have two pilots in all of them. I don't think we're considering that there is a cost trade-off. We think that stabilization is important and that we need two pilots, because of the operations that we do, the extended periods of time, if nothing else, the fatigue factors. All right, I think there is a lot of difference between the type of flying you are talking about and the flying we are talking about in the Navy. I can't address that for the other services, but I know – I'm almost positive that the Navy is not going to one pilot.

CAPTAIN MC ELREATH: But the Army mentioned they require a copilot to be along regardless of what the pilot's qualification might be on IFR flights. Where they do not require them is on VFR flights and it doesn't take very much to get, at least in the opinions of the Instrument Flight Center pilots, to get what they feel they need. The hover has some very bad directional stability problems, for example, and just a better paneling out with some meaningful instruments would help.

MR. SEGNER: But we have with adequate stability, whether it be augmented or otherwise, and I am not talking about the terminal approach where you need a unique Navy mission where you go through transition and a hover. As far back as 1956, we were flying IFR enroute in Japan continuously single pilot and in formation. This type of mission was easily done and as late as seven years ago when I had a reserve squadron, all pilots in order to become PPC's had to make four plane IFR GCA approaches on instruments, so the end we think is a function of how much stability the aircraft has and not whether you have dual pilots or not and what his workload is at the time, this is where the mission is so important.

MR. SCOTT OF SPERRY: Bob Tapscott, have you done much work on the instrumentation and autopilot combination in the airplane as far as keeping the pilot in the loop? To my knowledge there is no helicopter operational now today that has the degree of sophistication in flight control systems that even our smallest light Twins have. For instance, you can't take any one of the helicopters that we have been talking about and dial up heading select on the bug and have the autopilot do it. You have to still keep the pilot directly in that loop and he has to read the instrumentation, make a decision himself, and fly the airplane to that heading and then let the ASE, if you will, hold it steady. Have you done any work as to saying this is the way to go or that we should stay away from fixed wing or more automation than we have in the basic fixed wing?

MR. TAPSCOTT: I think when you say stay away from the amount of automation in the fixed wing aircraft, you should remember the program that John Garren discussed, we have gone all the way up to completely automatic VTOL approaches. This, of course, is straight in and we are now aiming towards the curved approaches, both in the vertical plane and in the horizontal plane. These do have the pilot in the loop, but I think we think of him more nearly interacting with an automatic system. I use the word automatic system but I don't really mean completely automatic operation. When you add a rate gyro, you're automating something in one sense of the word. But I think what you're asking is whether the pilot should have to put the aircraft in each new condition and then push a button and leave it there, and we are not aiming in that direction; we are aiming in the direction of keeping the pilot interactive with the system. Now, I think there needs to be a good bit of work done yet to define just what the pilot's role is in modern and in future aircraft display systems, and what they should really be. Someone mentioned here earlier, we talked about it's time to relieve the pilot of the task of stabilizing the aircraft and make a – for want of a better word – systems manager out of him. Now this may mean reallocation of all the controls that tie the pilot to the aircraft, and we are looking in this direction in some of our future programs. Now we have flown VTOL aircraft, I think with all degrees of sophistication, starting with the P1127, for example, which had nothing but basic ILS, no rate SAS, nothing to help the pilot. We did instrument approaches with that type of aircraft, right on up through using the XC-142, the DO-31 which had everything almost fully automatic, we have flown the CL-84 which you heard mentioned earlier, all of them with different degrees of automation in the flight control system and at different levels of sophistication in the displays, all the way from the abstract needles up through some pretty full flight director capability, and we find that the general capability of the pilot-vehicle system increases as you increase the level of sophistication. In fact, I think that we found that an attitude command control system and something better maybe than a flight director, a coupling of a flight director and a moving map display, would appear to us to be almost the minimum essential systems to keep the pilot active in the group.

MR. HAYDEN: I want to thank everybody. I think we had a real good panel and had a good interchange.

SESSION II

Panel 3

FUTURE NEEDS

MODERATOR

COLONEL WILLIAM E. CROUCH, JR.
OCRD

PANELISTS

MR. ARNO LINDER, ECOM

MR. EMIL SPEZIA, USAAAVS

LTC ROBERT WETHERBIE, USACDC

LTC WILLIAM FRENCH, OACSFOR

PHOTO 1. SESSION II. PANEL 3.

PHOTO 2. SESSION II. PANEL 3.

INTRODUCTION OF PANEL ON FUTURE NEEDS

COLONEL WILLIAM E. CROUCH, JR
OFFICE OF THE CHIEF OF RESEARCH AND DEVELOPMENT
DEPARTMENT OF ARMY

When Mr Charles Crawford asked me if I would chair this panel three or four months ago, I said yes, provided I could get the necessary travel funds. Needless to say, I did get the necessary travel funds but I bring the point up, just to preclude any wild stampede into OCRD next week trying to start big R&D programs in the area of instrumentation.

I suppose, when we discuss future needs, there are as many ideas on what we need as there are people in this audience. Many of you may have more than one idea on the subject. These ideas may range anywhere from needle, ball and airspeed to a very complex completely automated system. When we discuss future needs, we can't overlook the mission for which the helicopter was purchased. The pilot of the light observation helicopter is strictly an observer. He goes out and gains eyeball to eyeball contact locating targets. We must never lose sight of the fact that we design these aircraft and equipment for a specific mission. The people from ASTA told us yesterday that the LOH aircraft were not suitable for IFR flight. We never bought them for that purpose. How can they expect them to be suitable for it? The two contractors didn't design and build them for that purpose. I have on the stage up here this morning, four employees of the government. Later on COL Les Gilbert will chair a panel which will be represented by members of industry on what future needs are.

Our first representative will be Arno Linder from ECOM.

MR ARNO LINDER
US ARMY ELECTRONICS COMMAND

I had intended to read several paragraphs of a paper on Rotary Wing Cockpit Instrumentation by George Yingling of the Air Force Flight Dynamics Laboratory, Sol Domesheck of the Army Avionics Laboratory, and Professor George Rowland of the University of Pennsylvania. This paper discussed the instrumentation and stability augmentation needs to achieve "around the clock" all-weather helicopter operations. Written in 1967 and reread today, it is apparent that the problems that existed then are still with us, at least in the operational fleet. However, since General Maddox stated the needs so graphically yesterday, I've decided to spare you my reading this old document. Yesterday's presentations and discussions pointed out various systems and programs that could lead to the achievement of an improved operational IFR capability; having determined what we can do technologically we still must determine what we need operationally. What can we afford? What is the simplest, most cost effective configuration that will do the job and what is the job. Are we to continue to fly the helicopter as if it were a fixed wing aircraft or will we capitalize on and exploit its special characteristics? While we seem to have a pretty good handle on what we need for conventional IFR operations, it would seem the specific operational questions and technological answers relating to low-level tactical IFR operations, for example, have yet to be developed. As for future needs, I don't think we are ready to undertake the consideration of long-term future needs until we provide the answers to our current and near-term problems. If these solutions are well thought out, the future problems will be that much easier to solve.

COLONEL CROUCH: We will allow some time at the end after all the panel members have made their presentations, for any questions that you may have. In order to speed up some, we'll let Mr. Emil Spezia make his pitch at this time.

MR EMIL SPEZIA
US ARMY AGENCY FOR AVIATION SAFETY

What I have to say concerns the same problem area Mr Linder addressed; that is, I am concerned about the operational consequences of IMC flying. Specifically, I am going to use the occurrence of orientation error, the association of disorientation and instrument flight. Orientation error, as I will use it, involves the correct determination of the dynamic position and the attitude of an aircraft in three-dimensional space. The key word here is dynamic, which implies that the full knowledge of the motion as well as the static attitude and position is required to define its instantaneous spatial orientation. An aviator for my purposes here is considered to have made an orientation error whenever his perception of the motion and attitude of his aircraft differs from the true orientation of his aircraft. We define an orientation-error accident, then, as one that occurs when a pilot applies incorrect control or power because of his incorrect perception (or lack of perception) of the true orientation of his aircraft. Those of you who fly helicopters know what I am talking about – you know the stability of your cockpit is much like a pendulum hanging by a string.

First Slide (Slide 1)

So let's look at slide 1 which shows fixed and rotary wing orientation-error accidents during the ten-year period from FY 61 through FY 71. Over the years these accidents have accounted for 7% of all rotary wing and 2.8% of all fixed-wing aircraft accidents. Rotary wing experience shows an increasing trend to a high of 14.6% in FY 71.

We at USAAVS have been most aware of these accidents. Their occurrence and inherent severity came to our attention early in the development of the Army's concept for air mobility – the 11th Air Assault exercises had their share of occurrences to highlight the problem. USAAVS, USABAAR at that time, brought the problem to the attention of all who would listen. Needless to say, we didn't have much success getting the attention of the right agencies.

Sitting out there yesterday listening to the proceedings of this conference, I had the good feeling come over me that perhaps, finally, something was going to be done about solving or at least minimizing the orientation-error problem that has plagued our rotary wing aviators. What the solution will be I don't know. In fact, it is not USAAVS's responsibility to provide a solution but to define the problem as precisely as possible and then bring the problem to the attention of the appropriate agency for solution. USAAVS, as you may know, even though it took more than a decade, successfully defined the helicopter post-crash fire problem to bring about development of a crashworthy fuel system for these aircraft. I hope this conference is the beginning of the end for the orientation-error problem.

Next Slide (Slide 2)

For this slide, I selected one of the years from slide 1, FY 69 in this case, as an example of the cost of these accidents in terms of injury to personnel and damage to aircraft. Note that 20 of the 65 accidents were fatal and they cost $11.7M. These are significant figures, whatever your point of view may be. These accidents happen under all kinds of conditions; however, most of them occur in unexpected IMC flight conditions – haze, darkness, dust, night blindness from flares, searchlights – just the pilot's losing sight of the horizon for whatever the reason. An IFR flight plan was not involved in these accidents. Most of these young aviators were on tactical missions doing search and rescue, medical evacuation, perimeter defense, firefly (searchlight) search missions – combat flying for the most part.

As I mentioned, USAAVS tried to get the attention of responsible agencies and finally because of its physiological implications we got the ear of the Surgeon General, through Colonel Bailey, the commander of the Army's Aeromedical Research Laboratory at Fort Rucker. The figures you see on the slide are from a five-year (FY 67 – FY 72) longitudinal study of orientation-error accidents that was funded and conducted by the Laboratory. I am indeed grateful to Colonel Bailey. The study, accomplished without the aid of a computer, provides a case-by-case description of the pilot/aircraft/mission/environment found in these accidents in addition to determining cost and injury to personnel. The study is available to you upon request.

Next Slide (Slide 3)

The relationship of and need for instrument flight in the prevention of orientation-error accidents is well understood. To obtain an indication of the proficiency of our aviators for IFR flight, we included a question or two to this end in our 1971 accident prevention questionnaire distributed to Army aviators along with their annual written instrument flight examination. We asked the question, "How many hours of instrument flight time would you need with an instructor in order for you to fly first pilot in instrument meteorological conditions (IMC) safely?" These figures represent the response of approximately 8000 aviators. We divided the rotary wing and fixed wing aviators into two groups of aviators each – the desk (nonaviation) pilots and the nondesk (aviation) pilots.

The desk type rotary wing aviator said he needs approximately 15 hours with an instructor. Gentlemen, since we are concerned with rotary wing instrument flight, this slide shows the kind of aviator you need to design for. Also we can see the fixed wing aviator needs only five hours of instruction. This difference in instruction time is significant. It says to me that we have done an acceptable job to provide for the fixed wing aviator but we haven't for the rotary wing aviator and that is what this conference is all about. The problem is instrument flight proficiency. Why has it been so much more difficult for the rotary wing aviator? Part of the answer lies in the means, the aircraft, available to the rotary wing aviator to develop and maintain proficiency. As we all know, instrument flight skill is easily and quickly lost. We must make the task of maintaining proficiency easier for the rotary wing aviator. Such a comment often evokes the consideration of using synthetic trainers – that may be a way to go.

Years ago when we were trying to bring attention to the orientation-error problem, we talked to a number of manufacturers including Bell about an aircraft for instrument training. Bell responded with an unsolicited proposal that I still distribute whenever the opportunity arises. The proposal, which they demonstrated in a UH-1D, called for a kit for two fully instrumented positions, with flight controls and with blackout curtains in the cabin area. Though the idea never caught on, I am saying one of our future needs is not only flight instruments and stabilization, but the means by which rotary-wing aviators can maintain their instrument flight proficiency – hooded flight leaves much to be desired.

Next Slide (Slide 4)

I should mention all of the aviators represented by data on these slides had been trained and certified for instrument flight. This slide shows the need for instruction for fixed-wing aviators who are not current and those with the standard and special ticket.

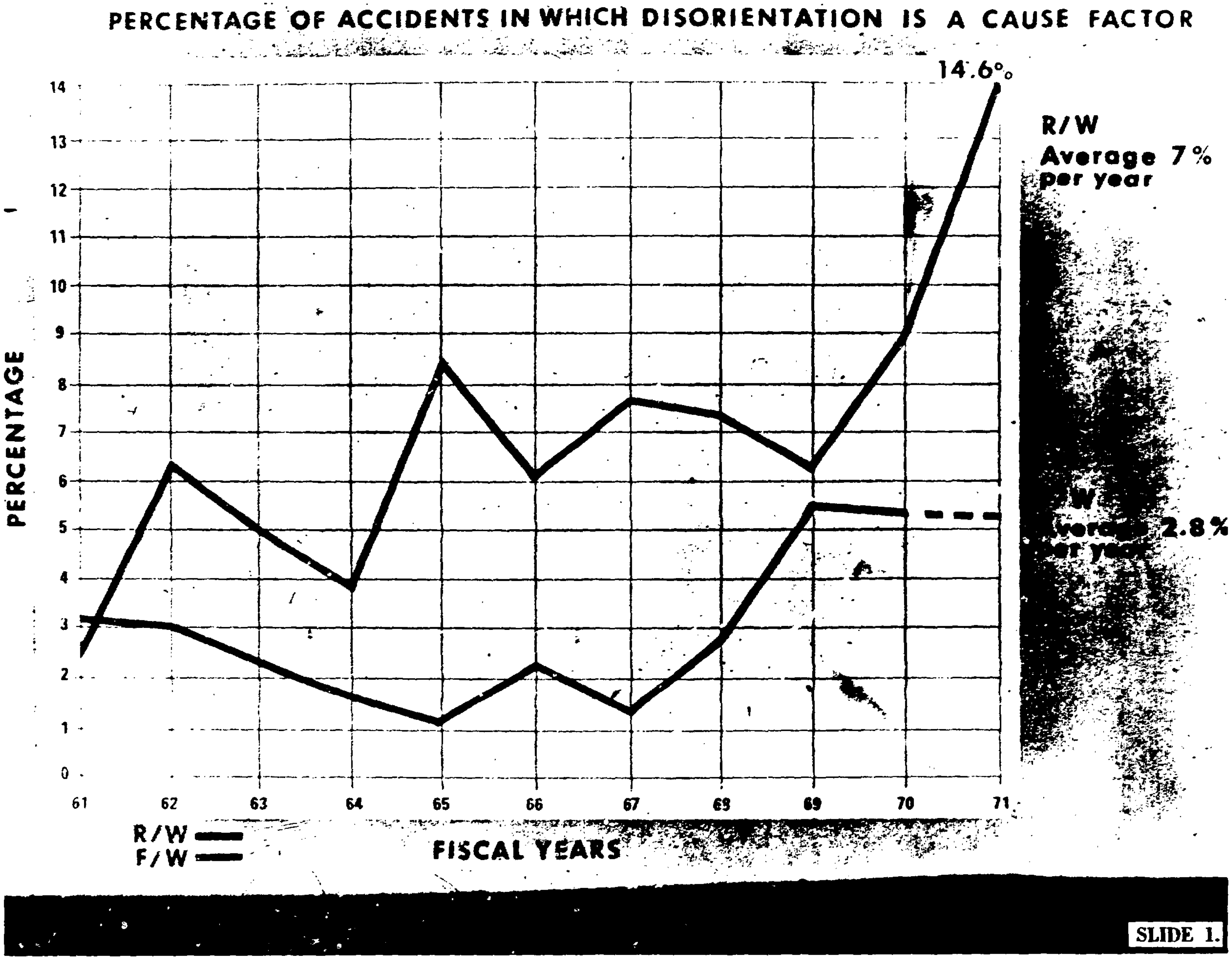
My concern, however, is for the rotary-wing aviator requirement for instruction. His requirements by qualification are shown in this slide.

Next Slide (Slide 5)

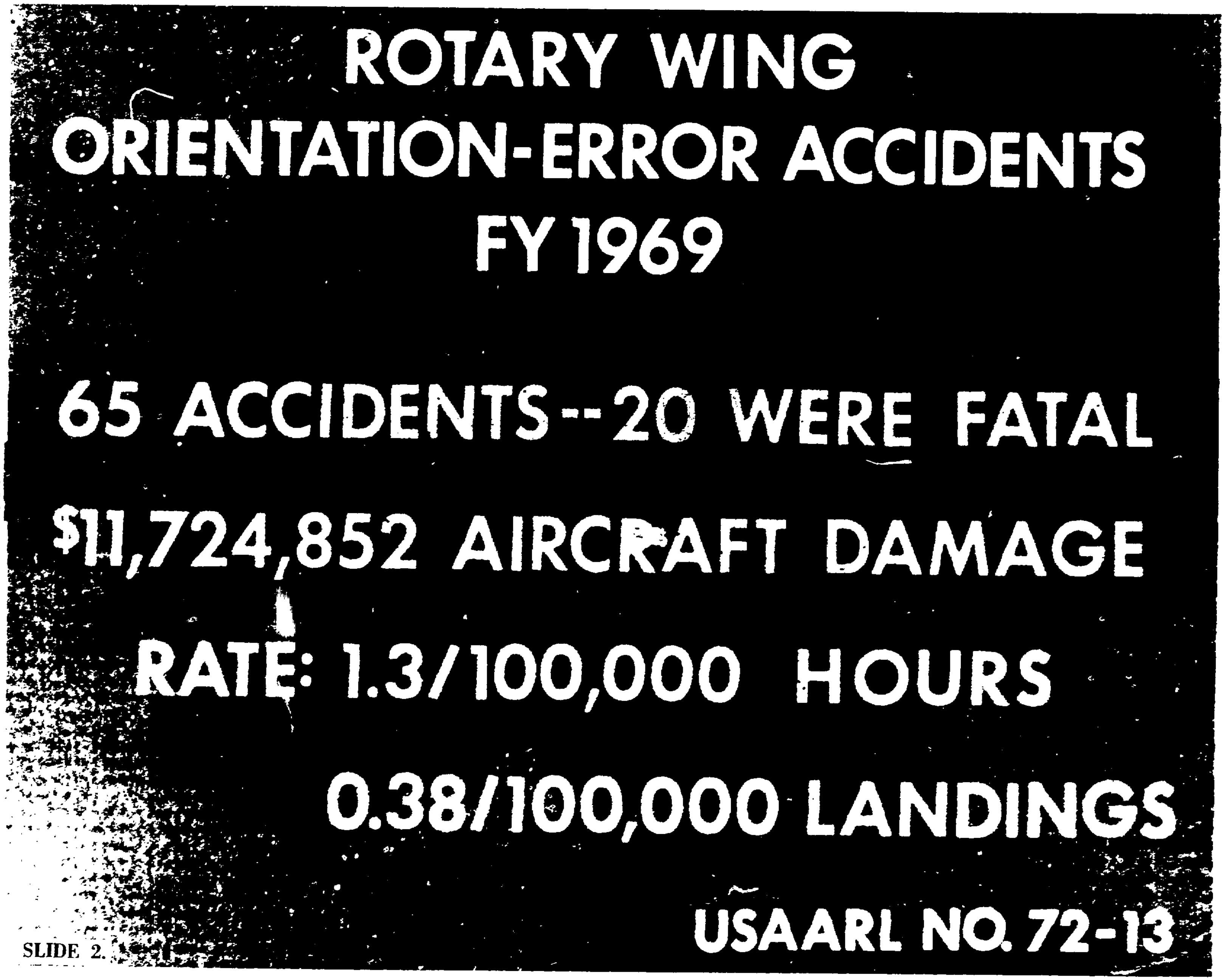
We see a much different picture. Rotary-wing aviators holding a tactical ticket in 1971 said they needed an average of 18 hours of instruction – this means these individuals are 18 hours, so to speak, behind the power curve of being able to cope with disorientation. The issuance of the tactical ticket has been damned; it has been cursed mainly because it has been abused by both the aviator and his commander – aviators went beyond their limitations and commanders expected more of these aviators than they were capable of. In spite of its criticism, if you had had the opportunity to study accident reports and had talked to the many aviators I have, you would have to agree the training they received was responsible for saving many of them – they learned how to keep the helicopter straight and level when conditions suddenly go marginal.

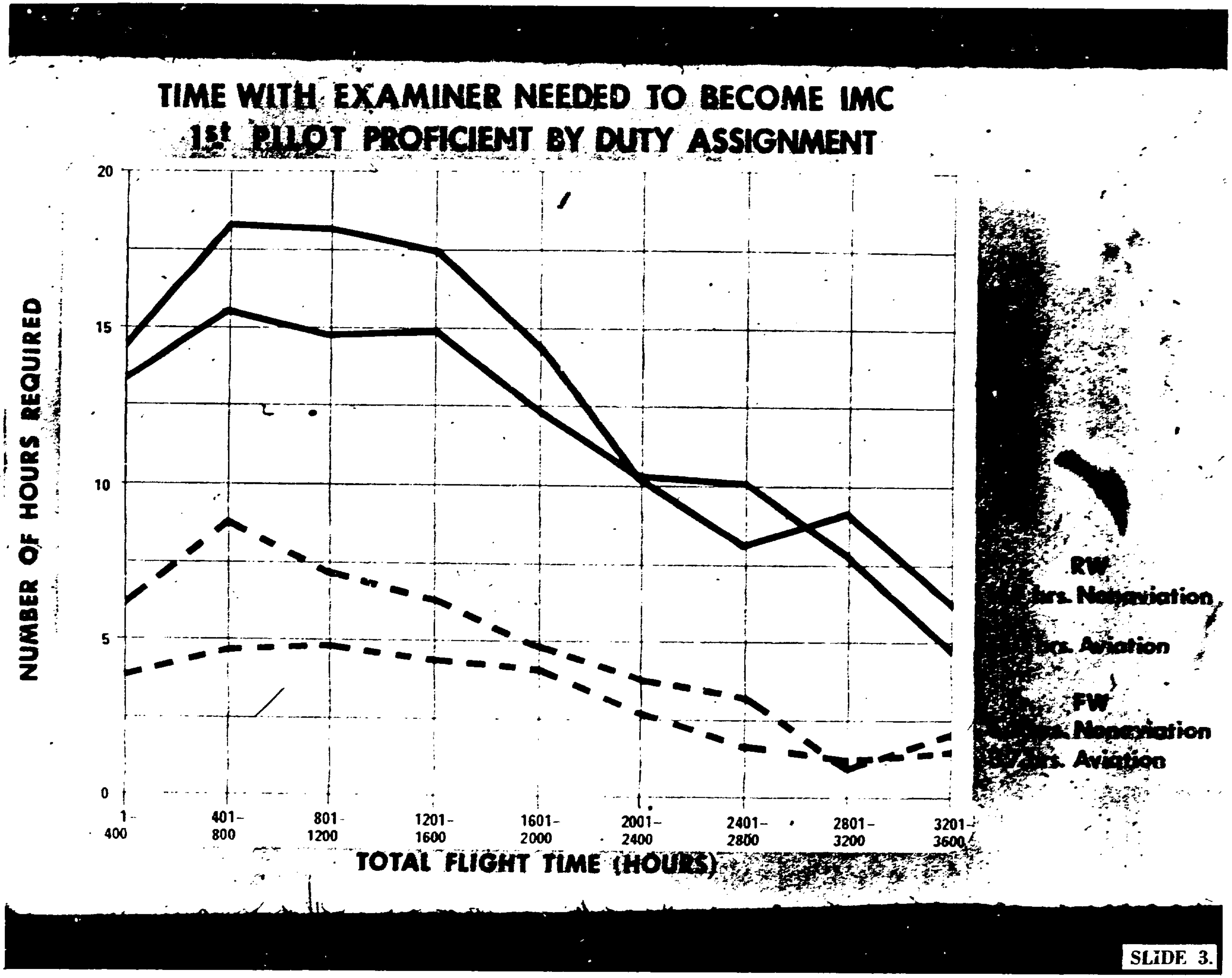
Note, however, the amount of time the standard ticket holder requires. His 4 hours are just slightly more than the 3.6 hours the fixed wing standard ticket holder required. On this basis, it would appear possible for the rotary-wing aviator to approach the proficiency of the fixed-wing aviator. Such observation, however, may be misleading because a significant number of the standard rotary-wing ticket holders were instrument flight instructors who, unlike the remainder, had the opportunity to stay reasonably proficient.

In closing, I want to make the point that our future needs today are the same as they were ten years ago. We must resolve instrument flight problems as they pertain to tactical flight. I have shown the consequences of letting these problems go unresolved. The high incidence of orientation-error accidents, their multimillion-dollar cost and, from a combat readiness point of view, the fact that rotary-wing aviators say they need 15 or more hours of instruction is justification enough to do what has to be done.

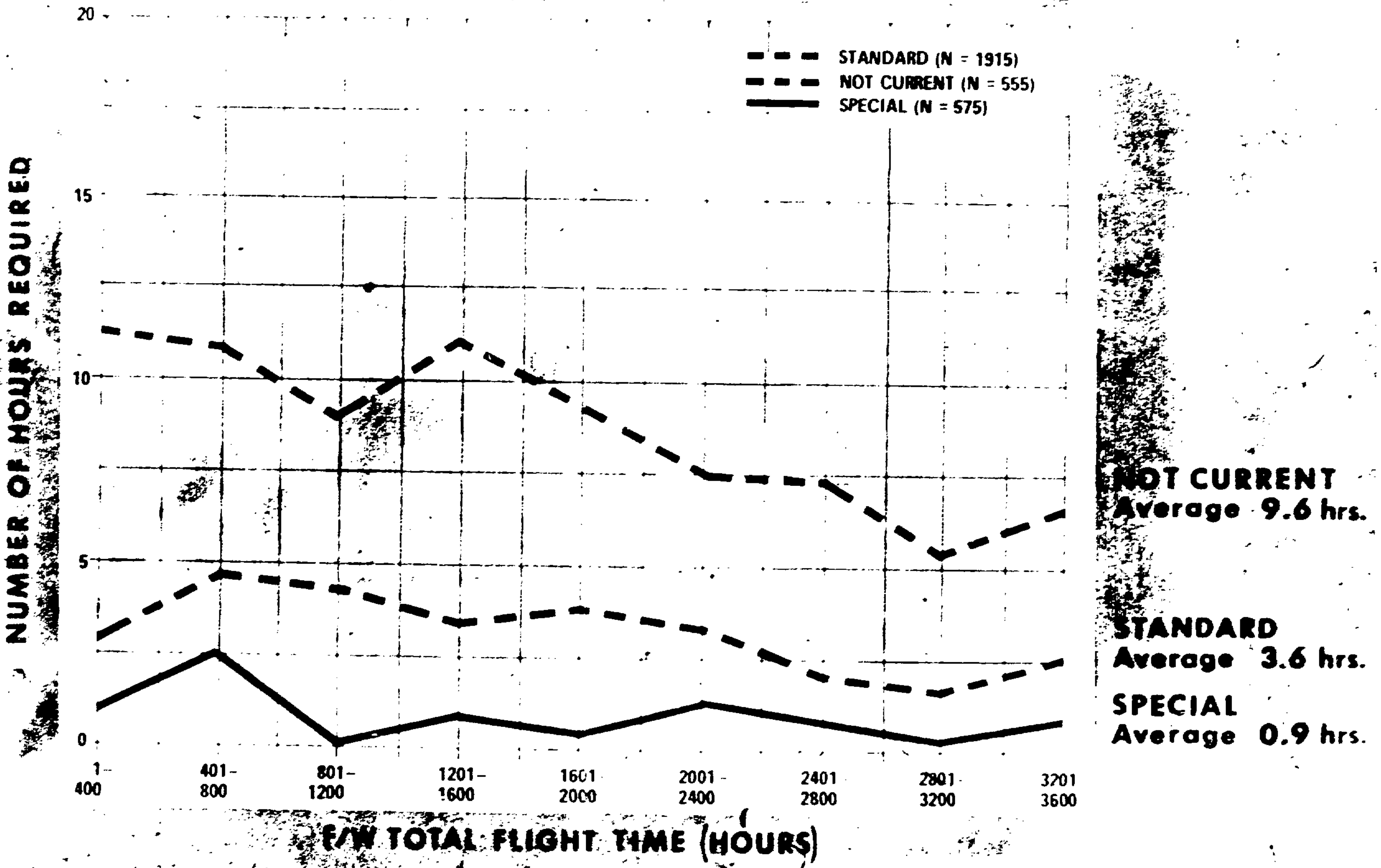


PERCENTAGE OF ACCIDENTS IN WHICH DISORIENTATION IS A CAUSE FACTOR
14.6%
R/W
Average 7%
per year
2.8%
PERCENTAGE
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
61
62
63
64
65
66
67
69
70
71
R/W
F/W
FISCAL YEARS
SLIDE 1.

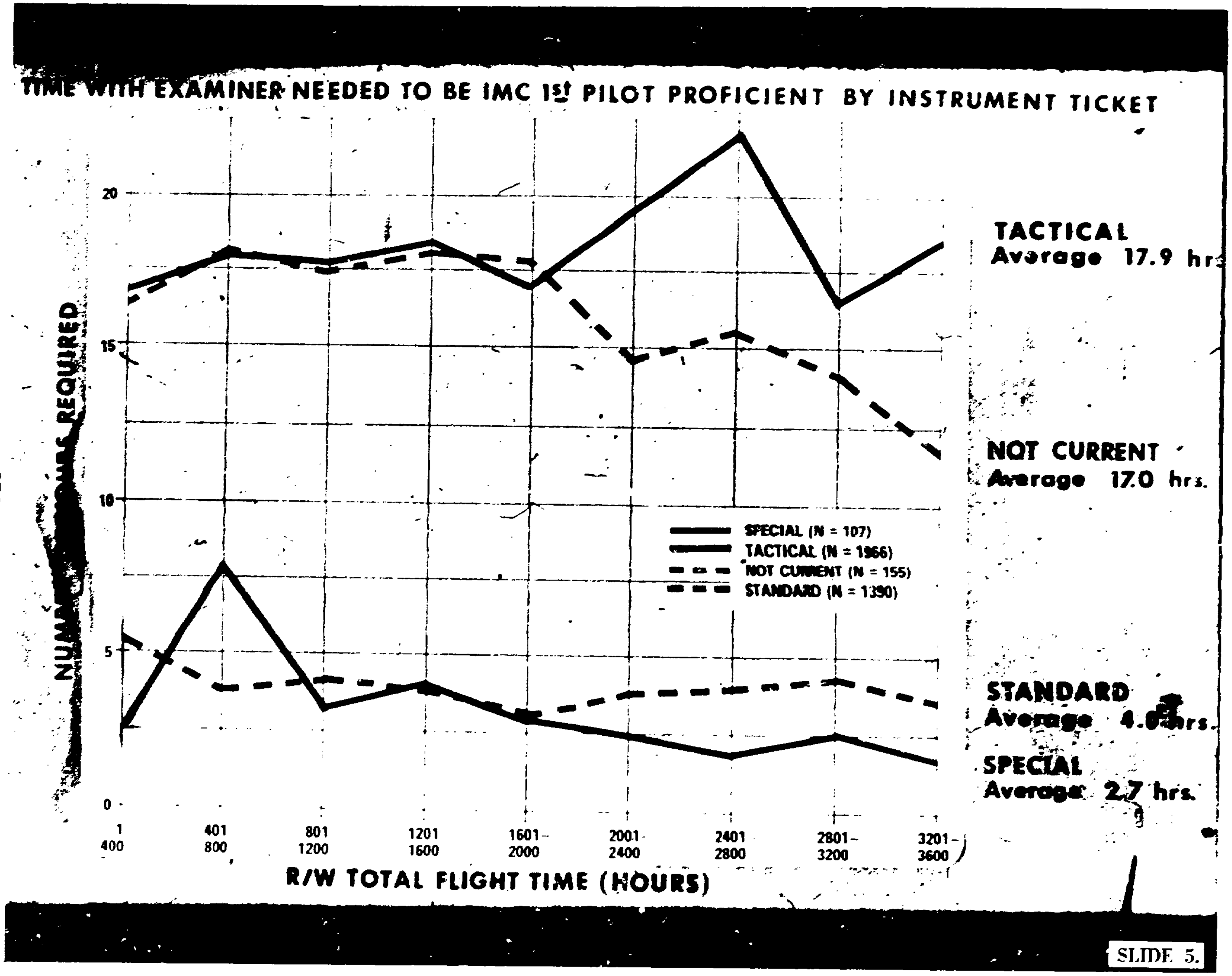

ROTARY WING
ORIENTATION-ERROR ACCIDENTS
FY 1969
65 ACCIDENTS--20 WERE FATAL
$11,724,852 AIRCRAFT DAMAGE
RATE: 1.3/100,000 HOURS
0.38/100,000 LANDINGS
USAARL NO. 72-13
SLIDE 2.


TIME WITH EXAMINER NEEDED TO BECOME IMC
1st PILOT PROFICIENT BY DUTY ASSIGNMENT
NUMBER OF HOURS REQUIRED
0
5
10
15
20
1-400
401-800
801-1200
1201-1600
1601-2000
2001-2400
2401-2800
2801-3200
3201-3600
TOTAL FLIGHT TIME (HOURS)
RW
FW
SLIDE 3.

TIME WITH EXAMINER NEEDED TO BECOME IMC 1st PILOT PROFICIENT BY INSTRUMENT TICKET



SLIDE 4.


TIME WITH EXAMINER NEEDED TO BE IMC 1st PILOT PROFICIENT BY INSTRUMENT TICKET
NUMBER OF HOURS REQUIRED
R/W TOTAL FLIGHT TIME (HOURS)
1-400
401-800
801-1200
1201-1600
1601-2000
2001-2400
2401-2800
2801-3200
3201-3600
0
5
10
15
20
SPECIAL (N = 107)
TACTICAL (N = 1966)
NOT CURRENT (N = 155)
STANDARD (N = 1390)
TACTICAL
Average 17.9 hrs.
NOT CURRENT
Average 17.0 hrs.
STANDARD
Average
SPECIAL
Average 2.7 hrs.
SLIDE 5.

GENERAL MADDOX: Every single Army aircraft we're going to develop from now on is going to be fully qualified for IFR flight, right from scratch. We're not going on the same basis as during Vietnam, where we were building airplanes for a specific environment to do a relatively narrow job. Now we have the problem of having to modify our aircraft so they'll accommodate flying conditions in the rest of the world. For instance, nobody thought or worried about icing conditions when we were building for Vietnam. Now we're straining greatly to solve the icing condition problem. Our new aircraft are going to be qualified for world-wide operation, visual and instrument.

COLONEL CROUCH: Our next panelist is LTC Bob Wetherbie from the Aviation Agency at Fort Rucker.

LIEUTENANT COLONEL ROBERT F. WETHERBIE
US ARMY COMBAT DEVELOPMENTS COMMAND

The purpose of my briefing will not be to give you a laundry list of required IFR instruments, but to provide you with a list of important considerations prior to entering into massive uncoordinated development programs. These considerations will be oriented toward mid-intensity conflict in Europe. The considerations are as follows:

1. Aircraft missions.

2. Tactical environment.

3. Current equipment capabilities.

4. Current human capabilities.

5. Aircraft base location.

Aircraft Missions. The Army has assigned specific missions to each aircraft, *ie*, our light observation helicopters acquire and identify enemy targets and direct our attack helicopters to attack positions who will in turn destroy the designated targets. Our utility helicopters accomplish troop lift, cargo helicopters deliver cargo, etc. It is vitally important that these missions be kept in mind.

Tactical Environment. We must consider the intensities of conflict, and the climates we will be working in, the altitudes the aircraft will be flying at, and the range they will have to fly to get to their destinations. Those of you that attended the recent Army Aviation Program Review at Fort Rucker recall there is a definite survivability curve starting 50 feet or below at the FEBA and slowly increasing in altitude as you reach brigade and division and corps boundaries. In these areas, if you expect to survive, you must be below the curve. The IFR requirements at these altitudes in these areas must be considered. The primary aircraft operating in these areas will be the observation, attack, and utility helicopters.

Current Equipment and Human Capabilities. We must be aware of our present capabilities. One rather impressive experiment being conducted at CDEC is 43.6 (Daylight Defense). This is a tremendous step in the right direction to ascertain what our capabilities are. Their pilots are flying at night with current instruments, including radar altimeter, down to about 200 feet AGL. I think this is one area we have neglected in the past, technology is about to overrun us and we are not sure what we can do with maximized training and current equipment. Sometimes we tend to sell our people a bit short. When we determine what equipment is needed to supplement our present capability, it must be reliable, small and light, and cost effective. We should replace and not add to the existing equipment that we have. It is ridiculous to install a new system and still retain the old system in the aircraft. We have neither space nor the time to observe both systems.

In addition, we still have only a crew of two in the majority of the aircraft that we will be flying in the future. Looking back at some of the past programs, the advanced attack helicopter, for example, I often think of the workload that we would have imposed on the crew of the AH-56. Let's suppose that the aircraft is flying IFR toward the FEBA. The crew is occupied with aircraft control, navigation, communication, to name a few, at some point the aircraft descends to VFR conditions and continues NOE. The crew is now faced with NOE navigation, enemy threat weapons, communication and armament preparation. Upon reaching the attack position the crew might well be called upon to engage a point target, suppress with the 30mm cannon, control the aircraft and communicate. In addition to the above listed problems, the crew must monitor engine and flight instruments, radar warning, and IR missile, proximity warning devices and other possible systems. The above requirements coupled with the hazards of flying an eight to ten-hour day under combat conditions places a considerable strain on the pilot. The development of a multitude of gadgets to assist the crew must be considered through a systems approach. If not, we will end up helping the crew to death.

Base Location of Aircraft. Where will the aircraft be maintained, how far will they have to fly to do their job? The trend is more and more towards living with the troops. Aircraft will not in most cases be called from corps or division rear to support front line battalions. They will be located at division/battalion level. They will be in the foxhole or as close as we can get them to it. This consideration will affect IFR requirements.

In summary, let's consider a systems approach to the problem. Equip the aircraft with IFR instruments that are commensurate with aircraft mission requirements and environment; consider nap-of-the-earth flight and the weather associated with these altitudes. Consider pilot capabilities; and lastly, let's consider what technology can do to supplement current capabilities and not what we can do for technology.

COLONEL CROUCH: Our next panelist is LTC Bill French from OACSFOR.

LIEUTENANT COLONEL WILLIAM C. FRENCH
OACSFOR

This is supposed to be a problem making and problem solving conference. Maybe we have at least solved a problem of getting a new name for flight directors. Sperry calls it a Helicopter Command Instrumentation System (HELCIS) which seems pretty good.

In OACSFOR aviation we have a group of old aviators who have all been in the field and really appreciate the need for good instruments. However, combined with the field requirements are the problems of obtaining dollars to buy everything we need. We develop priority lists including such things as instrumentation, CH-47 fleet modernization, Huey improvements, crashworthy fuel system, etc. Once we've compared priorities we try to determine what the minimum, adequate, and optimum requirements are and balance them against the money available. We also consider pilot workload; that is, can a mission presently be accomplished and be done safely.

For our instrumentation we have two requirements. First is to fight and fly and second is to maintain instrument proficiency and qualification. For the fight and fly requirement we need aircraft that aviators can fly and not be so busy that they can't fight. For this aircraft we need at least an inadvertent instrument capability. For the instrument proficiency requirement we need some good instrumentation plus some CONUS navigation radios. For numbers of instrument training aircraft, perhaps a certain percent of LOHs in each unit should be so equipped. We probably don't need to equip all of them.

When considering single versus dual pilots for instrument work we must consider the various missions. Our present LOHs were designed for single pilot operations. However, for night, nap-of-the-earth or marginal weather conditions, we don't want to send a single pilot with an unrated observer or gunner. The requirements document for the Advanced Aerial Scout calls for a pilot and copilot/observer. Because of parallax problems, there must either be dual instruments or the kind of instruments that can be read from either seat.

One last consideration – reliability. Since Army Aviation is said to be five to ten years behind in avionics maintenance, we must have high reliability in our instruments. If we can't have reliability we must have redundancy. Good reliability and maintainability must be built into our instruments because they won't do us any good if we can't keep them operating.

COLONEL CROUCH: Thank you, Bill. If anyone in the audience expected us to lay out a specific blueprint for future needs, I trust you're sadly disappointed at this time. What we have done is to pinpoint some of the problem areas, as we see them, some considerations for your efforts and thoughts in the future. Our future needs really are near time, almost present-day needs. There is a lot of exotic work being done, especially by ECOM, in vision-enhancing devices and presentation displays. The presentation that ASTA made yesterday and the conditions under which they tested were primarily related to what I would refer to as airline type IFR flying. Who knows what type of instrument displays that we are going to need for our future environment, the high or medium intensity battlefields of Europe? I can't visualize our present-day instrumentation systems being adequate for 50 feet, and below nap-of-the-earth and below. I think we have some real problems and from an R&D standpoint we are working on them. I don't think a flight director is the answer to our current LOH problem. Perhaps a somewhat improved attitude indicator over what we have presently is in order. We want the very best item of equipment we can get for the least amount of dollars and therein lies the rub.

We have made up about 15 or 20 minutes here. Does anyone from the floor have a discussion or questions they'd like to present to the panel? Mr Jim Hayden.

MR. HAYDEN: Running through the thread of our problem is this recurring question of training, and I'd like to quote from approximate numbers that were given to me on a tour of the American Airlines Flight Academy. American has dedicated themselves very heavily to the simulation area. They can take a 707 captain, give him 20 to 30 hours in a 747C simulator, give him an average 2.3 hours in the cockpit, and they cut him loose for the first seat, but for the first 10 hours he has to have a fully qualified captain sitting in the copilot's seat and I think that is pretty fantastic, and maybe it's an area that we could be looking into with the fantastic cost of operating our aircraft and maintaining proficiency.

LTC FRENCH: We are, Jimmy, the guy right in the front row there in the TW's is our synthetic flight trainer system, DASSO. Right now we have one module at Fort Rucker of the FSTS, which is a four-place Huey cockpit with a center instructor station. He can control four cockpits. This thing is a fantastic piece of equipment. Bob Hamilton has flown it, I have flown it, General Maddox has flown it. It's said that we get better than one to one trade-off. An hour in the simulator is better than 1 hour in the Huey. Perhaps that's so. You can crawl into that thing and you're airborne immediately, or ready for takeoff and eliminate a lot of the rather unessential stuff. Also, we are investigating and taking tests, and having studies made on how many hours we can reduce in certain areas. We at this time don't want to reduce our total in the air flying hours in our initial entry training course. We can reduce and we are reducing our instrument training course and examiner's course. At the present time, we are acquiring seven more modules to be put in at Fort Rucker, so that all of the troops going through down there will be getting more than the 7-1/2 hours they're getting right now. American Airlines isn't the initiator of this. Nippon, the Japanese, have been doing this for a long time. I have been told they get 24 hours in the simulator and a check ride in the bird, so we are really pushing on this and looking to be a forerunner in the services for helicopter simulation, and it's looking real good.

JOHN SOMSEL: On looking at Mr. Spezia's accident rate chart, I had essentially two questions; one was, has there ever been a study associated with the findings of ASTA about the handling qualities of current helicopters compared to the accident rate?

MR SPEZIA: No.

JOHN SOMSEL: Secondly, with respect to Army near-future needs with, for example, the HLH and UTTAS, are they being considered for IFR operation and if so, how will they incorporate avionics and stability augmentation forms necessary for sustained IFR flight?

GENERAL MADDOX: The UTTAS most assuredly. Now, the HLH is a little bit different type of a program. It's a very austere prototype effort. It's not that big an effort to qualify for IFR flight. However, if a decision were to be made to go to a production model, then again, it will be required to operate under IFR conditions, and have all the black boxes that would be needed to enhance that particular effort.

SESSION III

Panel 1

HARDWARE CAPABILITIES AND FUTURE NEEDS
AVIONICS MANUFACTURERS

MODERATOR

MR. JAMES HATCHER
AVSCOM

PANELISTS

MR. GEORGE RACEY, BENDIX AVIONICS

MR. JAMES A. KLEIN, COLLINS RADIO

MR. PHILIP G. COOPER, KAISER AEROSPACE

MR. JOHN DIETRICH, SPERRY RAND

MR. FLOYD SHACKLOCK, TELEDYNE RYAN

PHOTO 1. SESSION III. PANEL

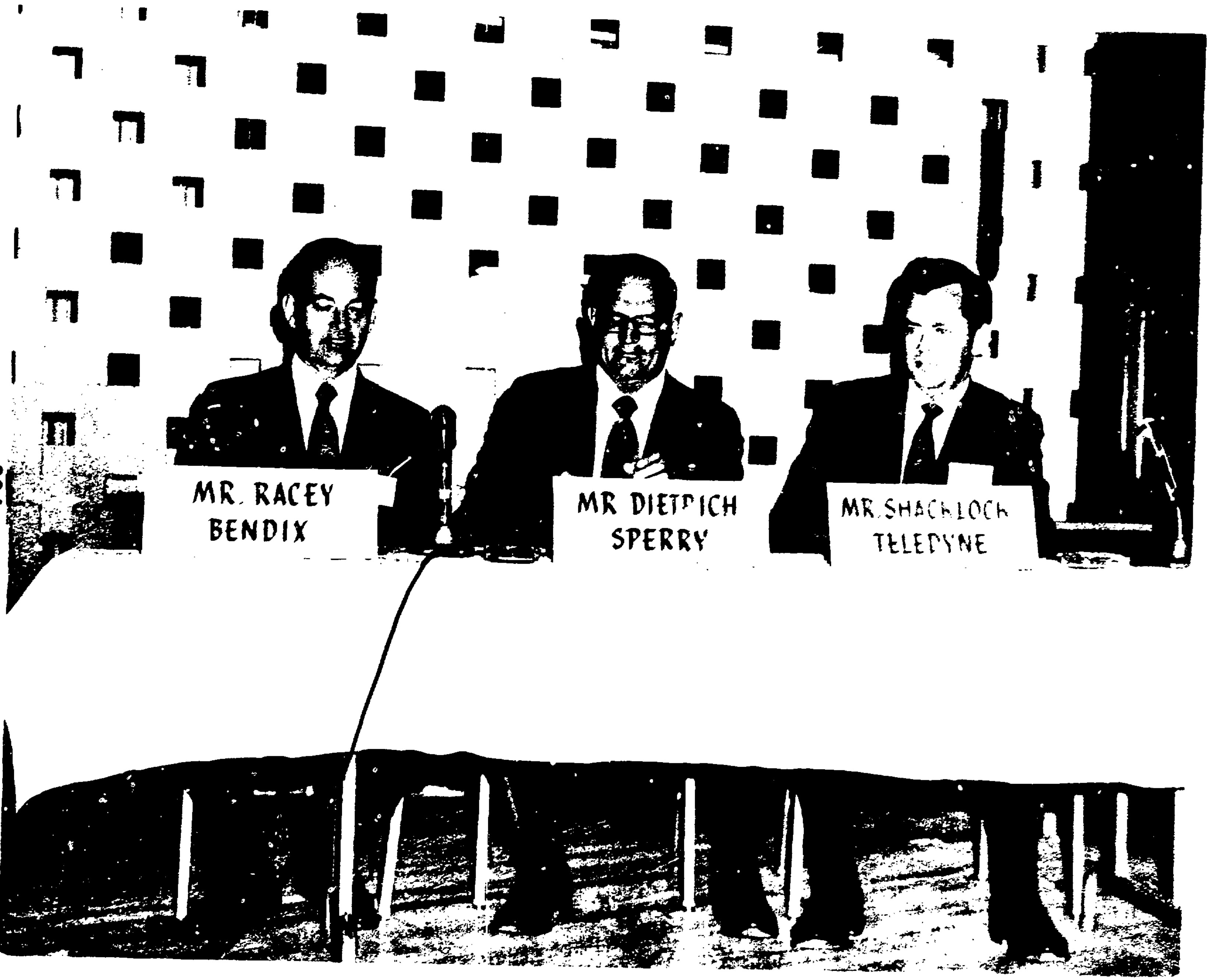


PHOTO 2. SESSION III. PANEL 2.

INTRODUCTION OF PANEL ON HARDWARE CAPABILITIES AND FUTURE NEEDS AVIONICS MANUFACTURERS

JAMES HATCHER
FLIGHT STANDARDS AND QUALIFICATION DIVISION
AVSCOM

Gentlemen, my name is Jim Hatcher and I'm with Flight Standards at AVSCOM and I'm here to introduce the industry members for this panel. However, I would like to set the context for their discussion in light of what we have already covered yesterday and especially the preceding session this morning. I think, in an attempt to complement what everyone else has said, we ought to look at the aircraft in four different realms. First, maintaining the platform in an upright position; secondly, maintaining the platform and navigating; thirdly, maintaining the platform, navigating and communicating; and fourthly, maintaining the platform, navigating, communicating, and being tactically effective. Naturally, there are different levels within each realm. For example, for the IFR platform, do we need to break out at a thousand feet, or we have requirements for 500 feet; the same for a hundred feet or fifty feet. On the other hand, is the operation planned or is it inadvertent? I think what these men are going to suggest we should listen to, take their recommendations, see where they apply, see what benefits we gain, and from that determine if the cost is realistic for the improvements that are provided, and then we can have a realistic approach of saying what is IFR, under what conditions, and for what purpose.

Let me start off with introducing Mr. George Racey of Bendix. Mr. Racey is presently the project engineer of the flight control group responsible for helicopter flight directors and stability augmentation systems at Bendix. Mr. Racey represents 18 years of experience in the development of automatic flight control, helicopter command instrumentation and navigational systems. Mr. Racey has pilot experience with the Royal Canadian Air Force and TransCanada Airlines. Mr. Racey's talk will be primarily centered around the Bendix helicopter command instrument system. Mr. Racey:

GEORGE RACEY
BENDIX AVIONICS DIVISION

This has been a very enlightening and interesting conference for me; hearing all the comments from so many experienced people in the helicopter field I think it's been very valuable to all of us in the avionics business.

As an instrument pilot myself, I realize that there is a great deal of concentration required in order to fly any aircraft under IFR conditions. A helicopter, being basically much more unstable than a fixed wing aircraft, therefore requires much more concentration to fly IFR. Several basic instruments must be scanned, all of your flight instrument group, their data mentally analyzed, and corrective action taken as necessary.

Now it's one thing to keep an aircraft right side up and pointed in the right direction in IFR conditions, but let's place our helicopter in an air traffic control environment, and we have a whole new list of duties. Our pilot now, in addition to scanning the basic instrument group, finds hemself having to communicate with the approach controller, center, or whatever ground facility he happens to be working. He finds himself having to select new communication frequencies and new navigational frequencies as he is handed from one controller to another. He's copying clearances, clearance amendments, changing transponder codes, and observing his enroute navigation charts and his approach plates, just to mention a few. In addition to all this, he has his flight instruments, engine, and other aircraft instruments to monitor.

I think we all agree that our helicopter pilot on instruments is a very busy man. Anything we can do to cut down his workload is certainly going to be a step in the right direction, and a good place to start in cutting down this workload would be to reduce the number of instruments our pilot must scan.

First slide, please (slide 1)

Now, if our pilot can maintain heading; fly constant altitude; navigate on VOR or ILS; home to an FM beacon or track to a nondirectional ADF beacon with reference to a single instrument rather than having to scan the whole flight group along the top here, definitely his life is a lot easier. Recognizing the need in the helicopter field, particularly in the LOH field that we have been involved in, for a lightweight, modestly priced flight director system with most of the capabilities of larger sophisticated systems, Bendix has introduced the FDS 840 helicopter flight director system. In this system, the design concepts have been deliberately kept simple.

Next slide, please (slide 2)

We have incorporated, in a ruggedized artificial horizon indicator, meter movements driving our flight director commands. This allows us to eliminate the more costly remote vertical gyro that we use in our sophisticated systems, plus an expensive servo-driven flight director indicator. In order to keep the cost down, many innovations have been introduced in this system without sacrificing ruggedness or performance.

Next slide, please (slide 3)

The companion instrument to our flight director is our horizontal situation display indicator, and again, this indicator - that's the one at the bottom here - combines information from multiple instruments, as you see here. These two are the basic instruments that you would be looking at, the one at the right is your azimuth indicator from your slaved gyro; the one on the left is your normal cross pointer navigation indicator. The horizontal situation display indicator combines information from both of those instruments. The pilot only has to look at one instrument, the one on the bottom, the horizontal situation display indicator, to read data he would normally have to read from two instruments. The nice feature of the horizontal situation display indicator is the fact that it is a pictorial instrument. You can tell at a glance where you are in relation to the selected nav course or selected localizer as well as see your heading. When you find yourself disoriented, one quick glance at the horizontal situation display indicator tells you where you are in relation to your selected nav situation.

Next slide, please (slide 4)

Here is a closeup of the horizontal situation display indicator. These flags, the NAV and HEADING flags at the top, would normally be retracted. Looking at the instrument, we find that we have selected a VOR 090 degree radial. The aircraft is in the center of the glass and we can see from the yellow right-left bar there that we have passed through the radial. The two from triangle here will be "to" in this position; if it's "from" down in this position here, it indicates that it is a radial from a VOR station. We have just passed through that radial and we are on a heading of 042 degrees.

Next slide, please (slide 5)

Here we see our helicopter on an ILS approach. The pilot has selected the 090-degree inbound localizer course. Flight director commands indicate a satisfied condition. He is in a slight nose-down attitude, localizer needle is centered, and he is just inside the outer marker on his ILS course.

Now, our system has been evaluated in the OH-58. We have been through the military potential test at the Test Board at Fort Rucker, as well as two installations in OH-6's at AVSCOM, plus a UH-1 at the ECOM Lakehurst facility. In the military potential evaluation, we provided the modes that were shown on the controller there; heading, altitude, VOR, ILS, reverse for back course. We also provided FM homing and ADF homing through the flight director. Those tests ended back at the end of the summer. Since that time we have continued with our development in the system and we now provide ADF tracking. In the ADF tracking, the pilot merely selects ADF on a switch on the instrument panel that says ADF or nav. He selects his ADF; he sets in the course that he wishes to fly to the ADF beacon, using, of course, the arrow on his horizontal situation display indicator; and he is now given commands to turn to and intercept the selected course to that nondirectional beacon at a maximum intercept angle of 45 degrees. As he becomes established on the ADF course, crosswind compensation is automatically fed in, and the net result of all of this is that he flies a straight line to the beacon on the selected course without having to do any mental calculations or computations of his own. The net result is the same as if he was doing an ADF tracking problem where he observed a drift angle first, then he compensated for crosswind, and finally arrived at the angle that would take him to the ADF beacon in a straight line over the ground. As he crosses the beacon, a bank angle command is shown as he goes through the cone of confusion; he will get a maximum bank angle of approximately 10 degrees commanded and if he elects to continue on that course he will continue to track that course outbound away from the beacon. Now for an ADF approach, he could elect as he crosses the beacon to select a new course away from the beacon, and some ADF approaches are like that. You fly to the beacon on one ADF course; you might track outbound and do a procedure turn on another course, then as you come in over the beacon, you change courses again. He can do all those maneuvers using this ADF tracking feature. So we feel this will greatly enhance the capabilities of our system in areas where ILS and VOR are not available.

Next slide, please (slide 6)

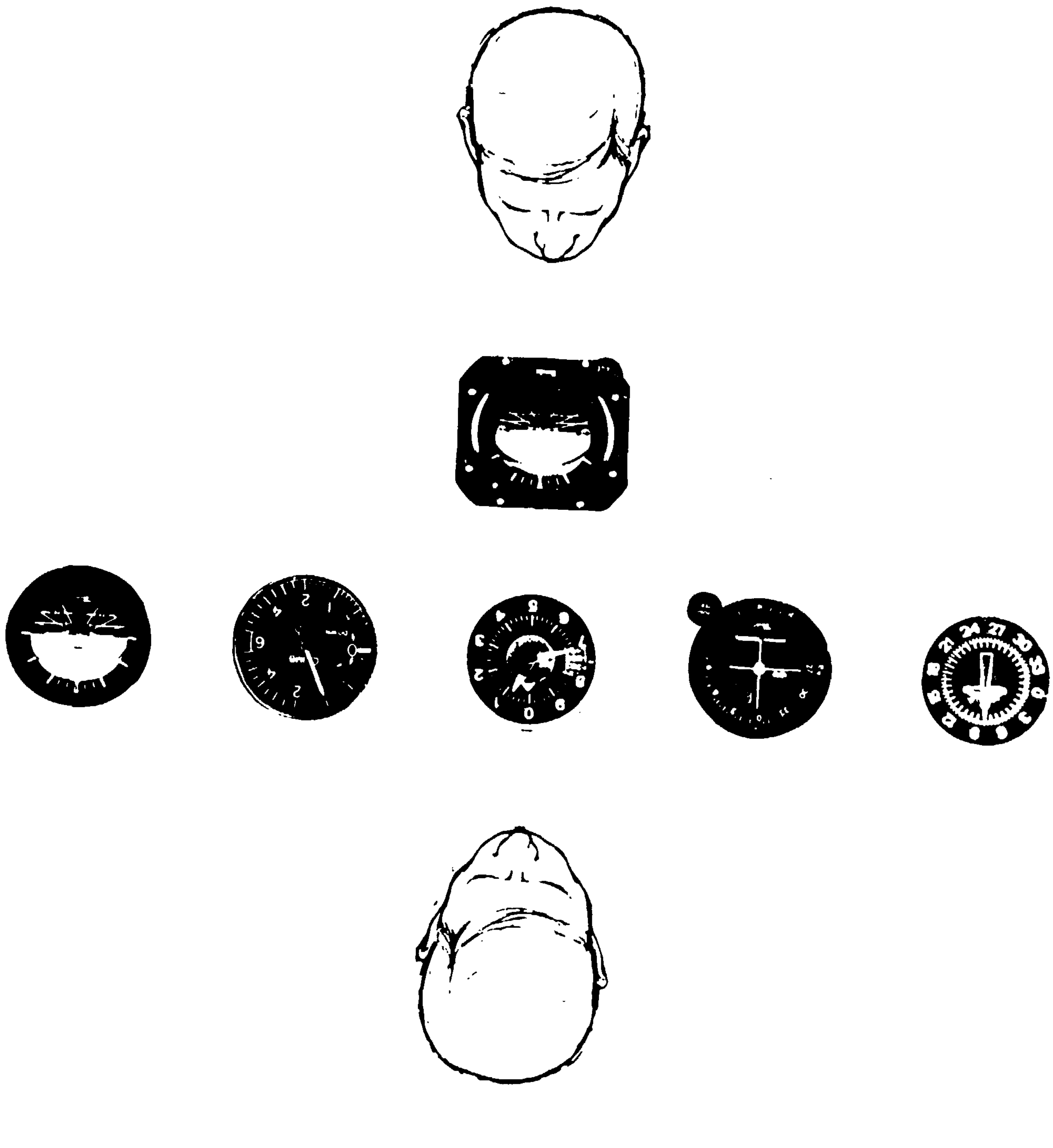
Here is a shot of the complete system. We have our flight controller, with all of its computer circuitry, our barometric altitude controller power adaptor, flight director indicator, our horizontal situation display indicator. These components were not used in the Army's evaluation because we tied into the existing compass equipment in the aircraft.

Much development work has been in progress at Bendix in the past several months on a low-cost stability augmentation system.

Next slide, please (slide 7)

Here we have a machine that some of you will probably recognize. It's the F-28 helicopter built up in Michigan. We have successfully evaluated our low-cost stability augmentation system in this aircraft and we anticipate, before the end of 1973, being certified in the aircraft. The system is very simple. It works through the existing trim actuators in the aircraft. The pilot, prior to engaging the system, just gets the helicopter at the attitude that he wishes to fly, roll, and pitch, and it's simply a matter of engaging the system. Now if he wishes to change attitudes, he has a little sync switch on the cyclic stick that he presses with his thumb. He can put the aircraft in whatever attitude he wishes, put it in a constant 10-degree bank or whatever he desires, release the sync switch, and he can fly it hands off and it will maintain that bank angle; in fact, it will maintain an orbit hands off at that bank angle. He can do the same thing in pitch. He can change pitch attitude, put it pitch-up or pitch-down with his thumb pressing the sync switch. As he releases the sync switch, the aircraft will maintain the new pitch attitude. We have a safety monitoring circuit in the system that monitors the integrity of the system in its operation. In the event of a signal that would cause a hardover malfunction, the system disengages automatically and the red engage light comes on on the instrument panel telling the pilot that he is back on manual flight. In other words, he can't get a runaway condition in roll or pitch. As soon as a signal of that type occurs, the system disengages and he gets a red warning light. So these are some of the things that Bendix has been actively engaged in during the past few years, and we feel that much of the technology that's been developed in these areas could be directly applied to the military LOH field. We thank you very much for the opportunity of participating in your conference here. It's been a real pleasure to me to hear all of these inputs from so many people of much experience

Thank you very much.



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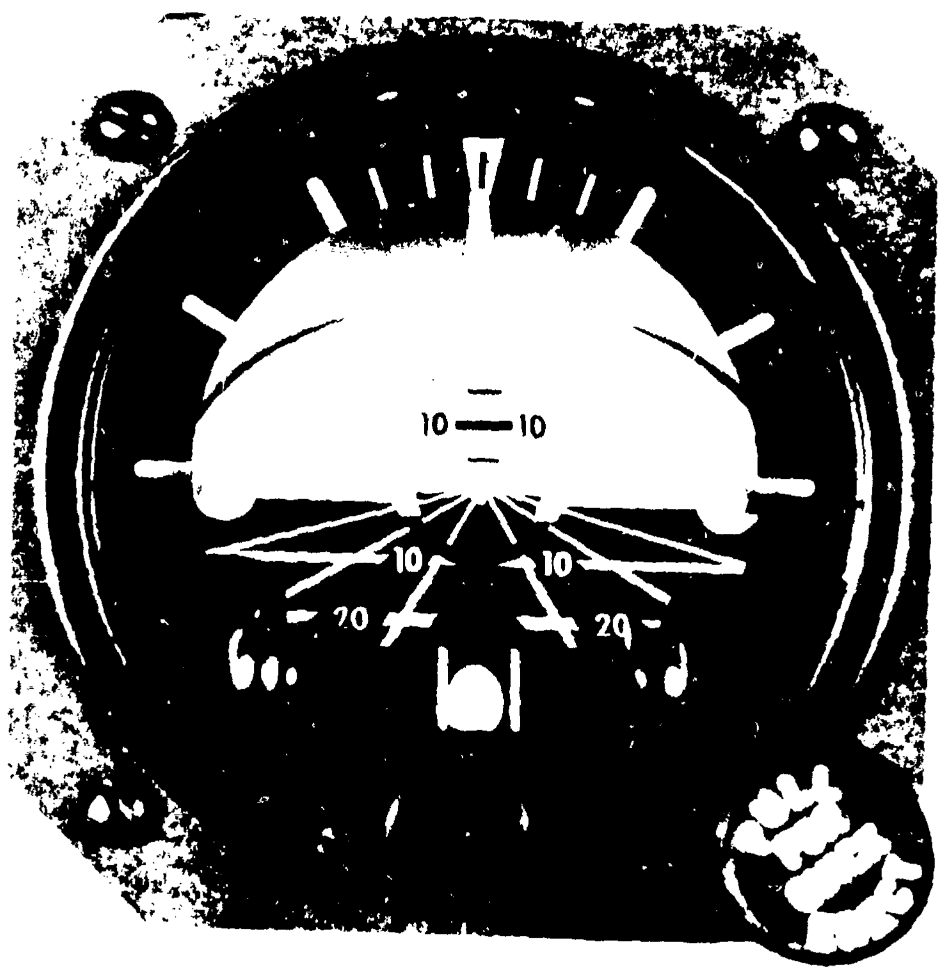

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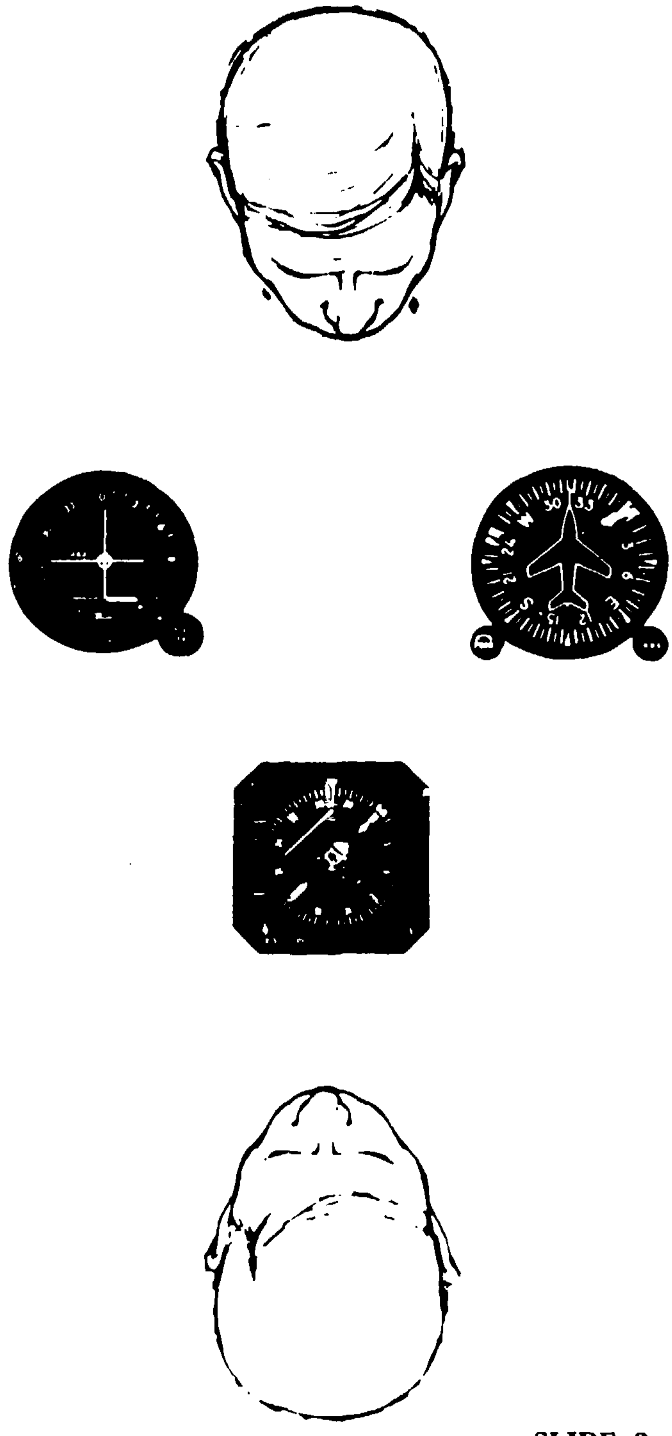

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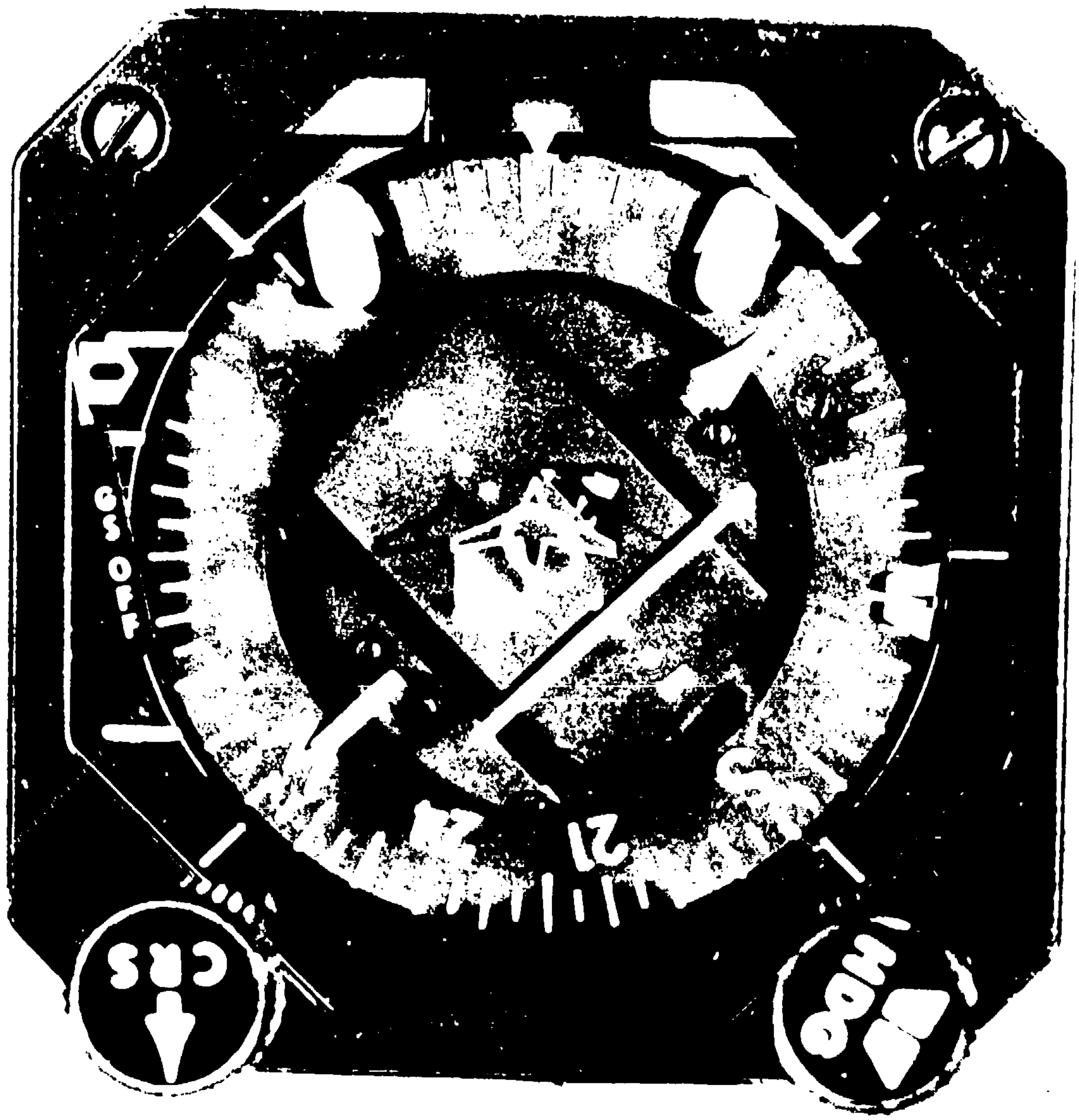

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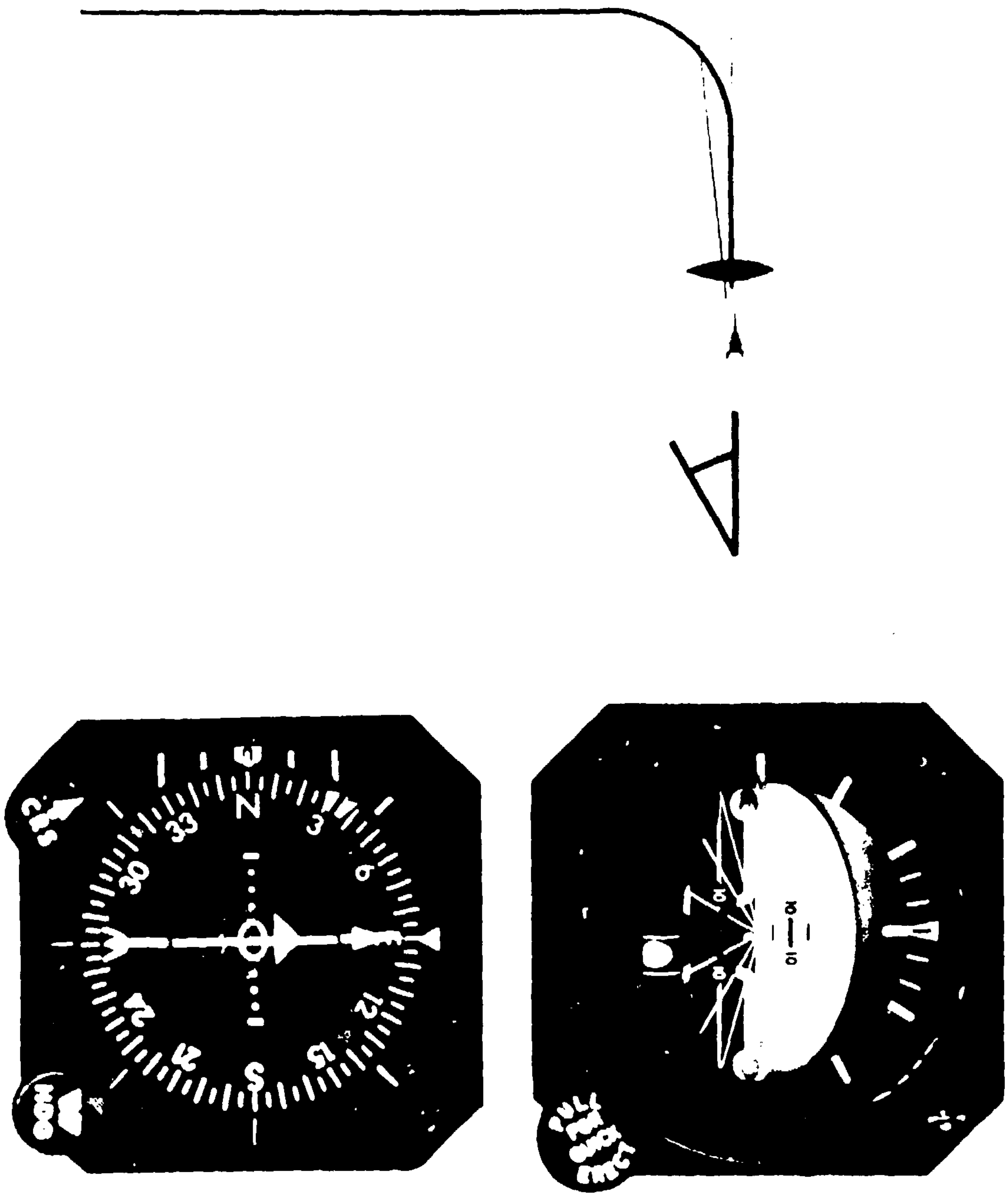

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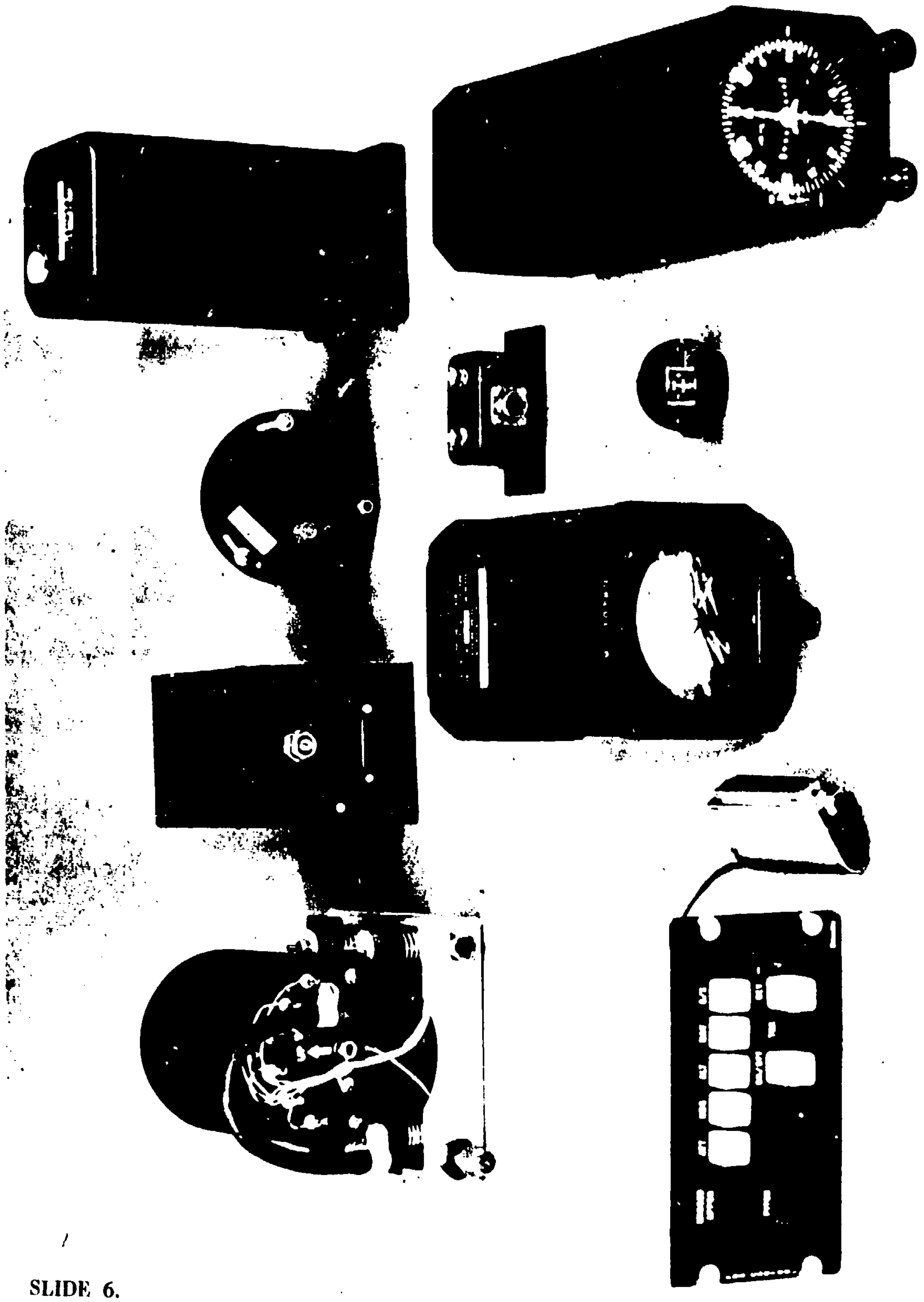
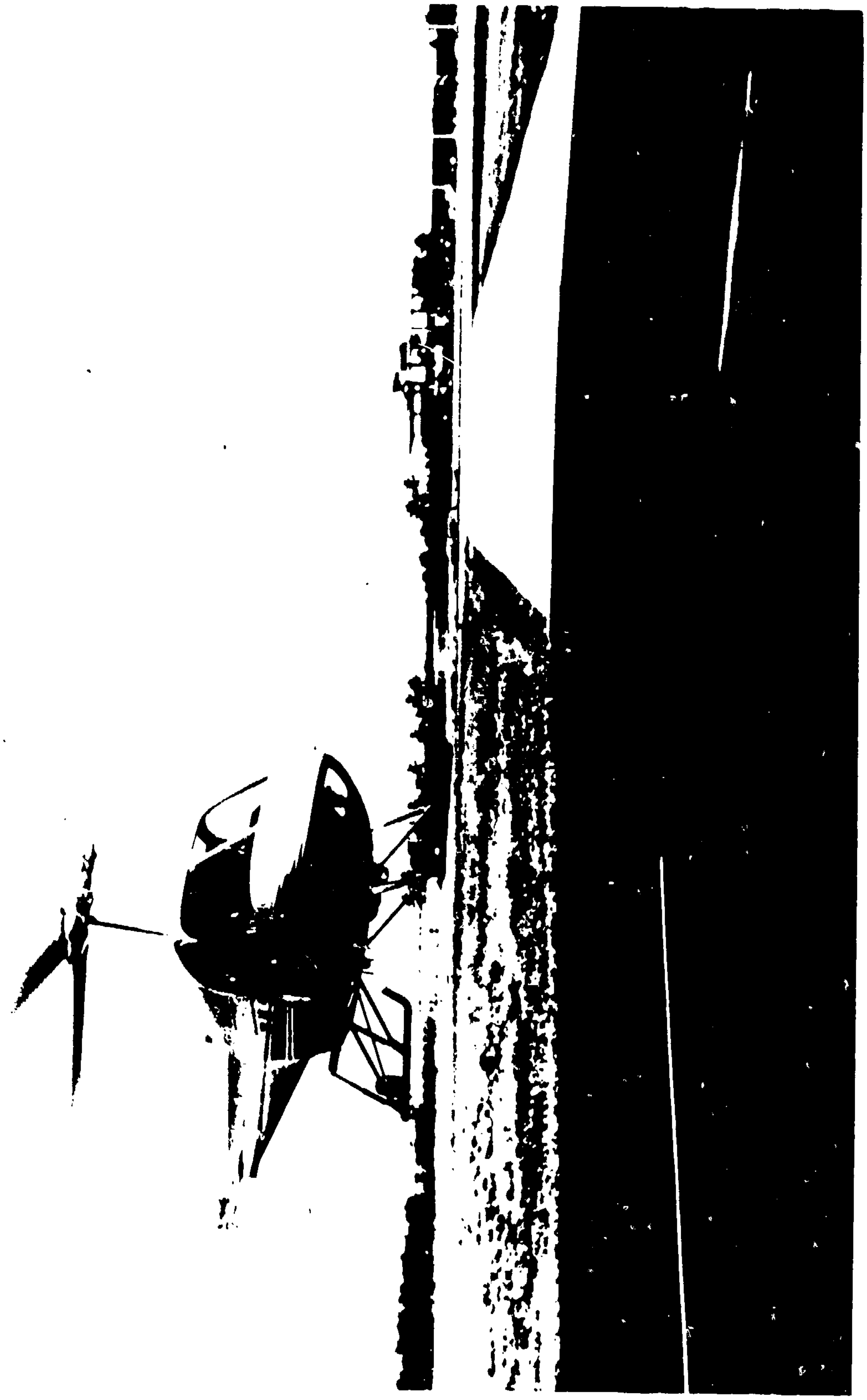


SLIDE 6.

SLIDE 6.



SLIDE 7.

MR. HATCHER: Thank you, George. Next is Mr. Phil Cooper of Kaiser Aerospace and Electronics; Mr. Cooper is in the marketing department and is responsible for the development of the Kaiser helicopter instrument command system. Mr. Cooper has been in circuit and systems designing, including head-up displays, flight directors, failure warning systems, and flight control simulation for the past several years. Mr. Cooper's talk will center primarily on computers and integrated display capability. Phil:

PHILIP G. COOPER
KAISER AEROSPACE AND ELECTRONICS

What I'd like to discuss is the problem of IFR flight control; the control laws involved in controlling helicopters; why 3-cue systems are desirable versus 2-cue systems; why, in fact, you need a computer at all to control your flight path in IFR weather; a little bit about what we've done here at ASTA, and then I'd like to speak a few minutes following that on integrated displays.

Slide off (introduction slide)

The flight control problem basically is one of low visibility and the corollary problem is obstacle avoidance, terrain avoidance, navigation, and, in tactical situations, ground fire avoidance and weapon delivery. These are all IFR flight control problems. I will segregate IFR flight control into four categories: takeoff, climb, enroute navigation, descent, and terrain following, or nap of the earth flying. Enroute navigation can be characterized by the fact that it takes place fairly far away from the ground, requires fairly low precision in the flight control aspect, and occurs for a fairly long duration. The other three categories I mentioned, takeoff, landing, or terrain following, however, occur in close proximity to the ground. They require establishment of a minimum clearance plane. They require high precision and fortunately, for the reason of requiring high precision, are of short duration. Speaking just a second on precision: in order to acquire precision in any flight control situation, whether IFR or VFR, the pilot is required to predict what the airplane is going to do before it does it. It is too late, once the error from the flight path has been established, for him to then get busy correcting the error. He has lost his precision. So prediction is the clue. The way he does precision flying in a VFR situation is by assessing the rates of change of certain situation data that is presented to him: attitude, altitude, or vertical speed, airspeed, etc. In the IFR situation, first of all, precision is required all the time in the three high-precision modes that I was discussing. The main difference between IFR and a VFR situation is the fact that with good visibility a pilot can essentially maintain a less precise control of the aircraft until he gets to the point in that mission where he really needs precision. For instance, in a landing situation, if he can see for miles, he can maintain just a rough approximation of his flight path until he gets close enough to the ground where he has to start being more precise. In IFR, because you don't know what's around you, you don't know where you are, as far as seeing whether you need precision, you must maintain precision all the time. Precision means fatigue. The more you work at it and the closer you control the flight path, the more tiring it is. Now, a flight path computer or flight director computer performs the same job that a pilot does in a VFR situation, but it takes the rates of change of certain situation data and it magnifies these rates to the pilot in an integrated form that is easily accessible. This allows him to maintain the same or better precision than he would have in a VFR situation, but with less workload. That, basically, is the definition of a flight director computer. Okay, now, based on the fact that I said we needed high precision for the three modes, takeoff, landing, and terrain following, I'd like to draw the conclusion, although I haven't given extensive support to that, that you require a computer or computed commands to obtain that precision.

Flight path control in rotary wing aircraft means, basically, control in three axes: the lateral axis with roll and yaw attitude as the primary inputs; the vertical axis, in this case, controlling vertical speed; and the longitudinal axis, airspeed. While these same axes are required to be controlled in fixed wing aircraft, there is a basic difference between the two, which I can describe by a series of simplistic control laws that I have written for rotary wing and fixed wing aircraft.

First slide, please (slide 1)

For fixed wing aircraft, a pitch change changes the angle of attack of the airplane, which changes the lift factor which modifies the vertical speed. A power change changes the thrust, which produces a change in airspeed. However, rotary wing control laws provide that a pitch change will change thrust, which will produce a change in airspeed. Power change will change lift, which will change vertical speed. You all know that. I just want to reiterate because it bears on the next subject that I want to talk on.

May I have the overlay, please.

This is a helicopter in an IFR landing situation. At point 1, we assume that we look at what he should be told to do in order to establish himself on the glide slope. Now let me, for example, take and apply fixed wing control laws to this helicopter in position No. 1. The fixed wing control law says to modify his vertical speed, which is what he must do to get on the glide slope; he must pitch down. Now we look at what the airplane really does when you pitch down; we provide change in airspeed and increase in airspeed; this puts him at position No. 2. He will lose lift, he will start to go down, but the significant thing to remember is that he will get a fast increase in airspeed, particularly in a light aircraft with short moments of inertia, and he will get in a divergent situation where the more he pitches, the higher the airspeed goes: it's a cumulative effect. It's a rapidly accelerating situation. If he had, however, applied the rotary wing control laws, he would have been required to reduce power, which would have established him on the guide slope with very little increase in airspeed.

Slide off, please.

Kaiser has built a flight director system based on rotary wing control laws. It has been installed in an OH-6 at ASTA for roughly 6 months, and has been flight-tested under the guidance of Major Griffith, who is project pilot. You heard from him yesterday on his testing, so I'll not cover that in any detail. What I would like to discuss briefly is the capabilities of that computer. It provides lateral steering commands to follow a magnetic heading, to home on an FM station, to intercept and track a course to an ADF beacon, to intercept and track a VOR radial, and to make a localizer approach. In the vertical axis, it will provide collective and longitudinal cyclic commands to maintain a barometric altitude and airspeed and in all of these vertical modes that I have discussed. we maintain airspeed as well as vertical speed.

Next slide, please (slide 2)

In the glide slope mode, we provide collective commands to maintain a glide slope and we maintain airspeed along that glide slope as shown in this graph. It maintains a constant airspeed as you come down until you reach a point 300 feet from the ground, where we begin energy management of the situation. We start reducing airspeed until we get to 50 feet, at which point we are at 40 knots, and we then reduce at a different slope down to 25 knots.

Next slide, please (slide 3)

In a normal descent mode we maintain a barometric rate and airspeed consistent with a 5-degree approach. This is not based on any outside reference at all. This is an autonomous descent. The curve shows what happens in an energy management situation as we get down close to the ground; as we pass through 300 feet, we reduce vertical speed from 700 feet per minute descent down to zero feet per minute at 50 feet altitude. Correspondingly with airspeed, we reduce airspeed down to 40 knots at 50 feet. Now, you might wonder why we just didn't reduce it to zero. It seems reasonable on the surface, perhaps. The problem lies in the lack of an adequate low-airspeed sensor.

May I have the overlay, please.

That is a rough sketch of the deadman's curve for a single-engine aircraft, and particularly for an OH-6. We don't want to plan to take him through the center of that in case of loss of engine. That's why we are bending around the lower end of that curve.

Next slide, please (slide 4)

The system also provides a 10-degree or steep angle descent, which operates under the same rules as this 5-degree descent. In this case, you come down at a thousand feet per minute until you reach 400 feet where we begin the energy management situation. Again, we reduce to zero feet per minute at 50 feet. In airspeed we start managing airspeed again from 60 knots at 400 feet down to 40 knots at 50 feet.

Overlay, please. That's the deadman's curve there. Slide off, please.

The system also has a missed-approach or go-around mode that also functions as a climb command for maneuvering, say, in a terminal area. In the future, it will incorporate in our next installation a precision hover mode using doppler reference. The point I would like to make at this time is that the capability to make IFR landings is here now. The technology is here. Now, what do I see in the future? In the future, I think we have to look at providing flexibility for growth, for tactical operations primarily. I feel that in addition to the information that we are providing, weapon delivery information and this sort of information is available at a very small increase in complexity in the cockpit. Things like TV-guided weapons, for example, are very easily integrated into a system of this sort. We have done weapon delivery work already at Fort Hood and Fort Belvoir, where we installed one of these systems and used it for night rocket delivery with very good results, good accuracy, accuracy comparable to VFR daytime rocket delivery. Enough of that.

Let's move on to displays. Mr. Racey has already discussed the concept of integrating displays. This is a very important concept as you strive for the precision required in IFR flight. You have to cut down on the scan pattern, you have to spend more time looking at what really is important. The thing that's telling you what is going to happen is the rates, what's going to happen to the situation before it changes. Integrated displays, horizontal situation as well as vertical situation, are required, if only from the fatigue point. However, we feel from the precision point, you benefit as well. Mr. Racey described a vertical situation display which uses electromechanical techniques for displaying the information. We have approached the thing from a different point of view, but we display basically the same information. We use a cathode ray tube or television display to display the same information. We prefer and we chose a CRT because it provides first of all an easy way of giving you a third cue. We feel that pictorial presentations provide a quicker acceptance of data, particularly in high tension situations. Instead of popping a flag at the periphery of your vision when a sensor fails, such as a compass system, we can actually put that information into the integrated command, and in the system at ASTA we flash the command to attract the pilot's attention. He doesn't have to look away to the periphery of his vision to find out if there is a failure. In the second installation that we are planning that is coming up soon, we will put FLIR video in the background behind that symbology so the pilot will have not only computer command information, but he will have video from a FLIR system. We feel this is the only way to provide the flexibility that future requirements are going to ask of you. The CRT is not a new thing in military aircraft. They have been used in many areas and I'd like to show you a couple of pictures of some that have been used.

Next slide, please (slide 5)

This is the vertical situation display in the Navy A6A, built by Kaiser. In the three pictures to the right, the top picture shows a forward looking infrared picture with symbolic attitude and command information superimposed. The center picture is a terrain following shades-of-grey radar picture showing range contours at one-mile ranges from the aircraft. The bottom picture is a synthetic attitude director indicator, with command symbology in the form of an inverted V and artificial horizon.

Next slide, please (slide 6)

A more sophisticated display was provided for the FAA several years ago. This system integrates even more situation information into the picture. Magnetic heading is shown on the top scale in the center of the display riding just above the horizon. We show on the left-hand scale raw-data glide slope, on the scale at the bottom raw-data localizer, radar altitude on the tape scale to the right, and crab angle is shown by an apex of that flight path. In addition, speed command is shown by the fact that the dashes in the centerline of that flight path will move if you're either too fast or too slow. A 3-axis command symbol is shown in the center right behind the aircraft symbol, in addition, of course, to the basic artificial horizon display.

Next slide, please (slide 7)

This is the Kaiser vertical situation display that is in the Navy F-14A aircraft. This shows again the artificial horizon, the vertical bar is lateral steering. In addition, the little tick marks show minimum and maximum range to a radar target and the actual range is shown by the center tick mark. The circle in the center shows allowable steering error for weapon delivery. The inverted "T" is a 3-axis command symbology and at the top you see a magnetic heading; pitch lines are shown also. One advantage I'd like to point out about electronic displays, by the way; you can change pitch sensitivity with the mode of flight that you're in. For example, you can have a different pitch sensitivity in a landing situation than in the enroute situation.

Next slide, please (slide 8)

This is the flight director on the OH-6 at ASTA right now.

Next slide, please (slide 9)

This is the OH-6 panel with a little buddy panel to the right where we have installed the flight director system, HSI and RMI, going down the panel, vertical speed indicator, barometric altitude, radar altitude, and turn and slip.

Next slide, please (slide 10)

A different kind of an integrated display is a horizontal situation indicator. You can also do it with TV. Here it is.

Next slide, please (slide 11)

This is a heads-up display, in fact, the F-14 heads-up display made by Kaiser where we show all this same situation and command information, but superimposed against the real world and focused at infinity, so the pilot doesn't have to look in the cockpit at all. We show magnetic heading, this diagonal line is a bomb-fall line for iron bombs or things of that sort, with a little bracket showing the pull-up cue. Altitude off to the right, target symbol to the left, and basic attitude.

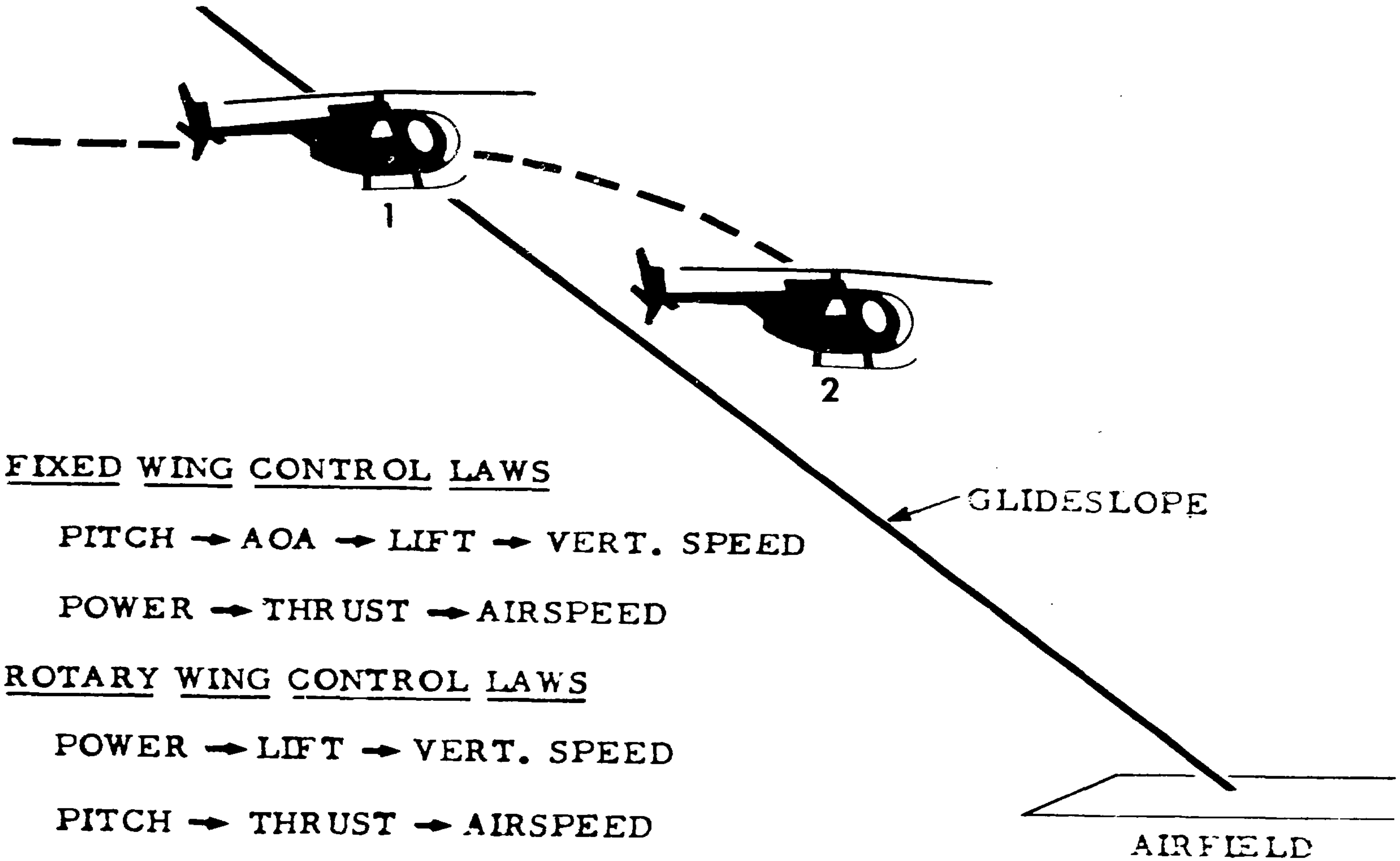
Slide off, please.

Despite what you might have heard about CRT's reliability or viewability, I'd like to make one thing clear, if it's the only thing I get across today. It's not true. They're in airplanes, they're flying, they're operational; they work, and they're durable. I'd like to make one last comparison for you. We compared our 5-inch system that is in the OH-6 right now to a comparable 5-inch electromechanical system and it is lighter, uses less panel space, has greater flexibility and utility, and reliability, and it costs the same or less.

Next slide, please (slide 12)

In summary, I'd like to make four points. I feel that for the three modes of IFR flight that I talked about, that is, takeoff, landing, and terrain following, a computer is required. Further, a 3-cue or more accurately, a rotary wing computer is required. The technology is here. It has been done. It works. A CRT provides you with future, with growth at no penalty, plus it gives you a sensor display on that panel for those aircraft that you wish to install those things in.

INTRODUCTORY SLIDE.



FIXED WING CONTROL LAWS

PITCH → AOA → LIFT → VERT. SPEED

POWER → THRUST → AIRSPEED

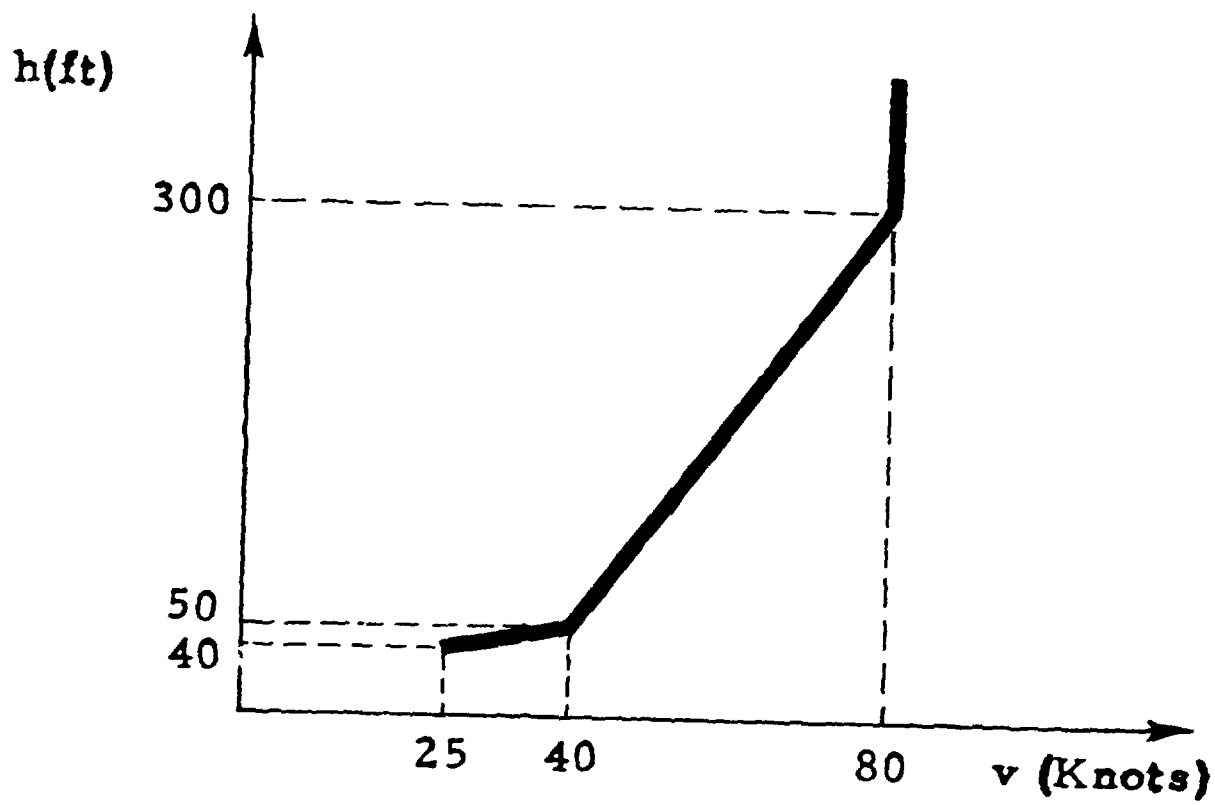
ROTARY WING CONTROL LAWS

POWER → LIFT → VERT. SPEED

PITCH → THRUST → AIRSPEED

KAISER AEROSPACE & ELECTRONICS

SLIDE 1

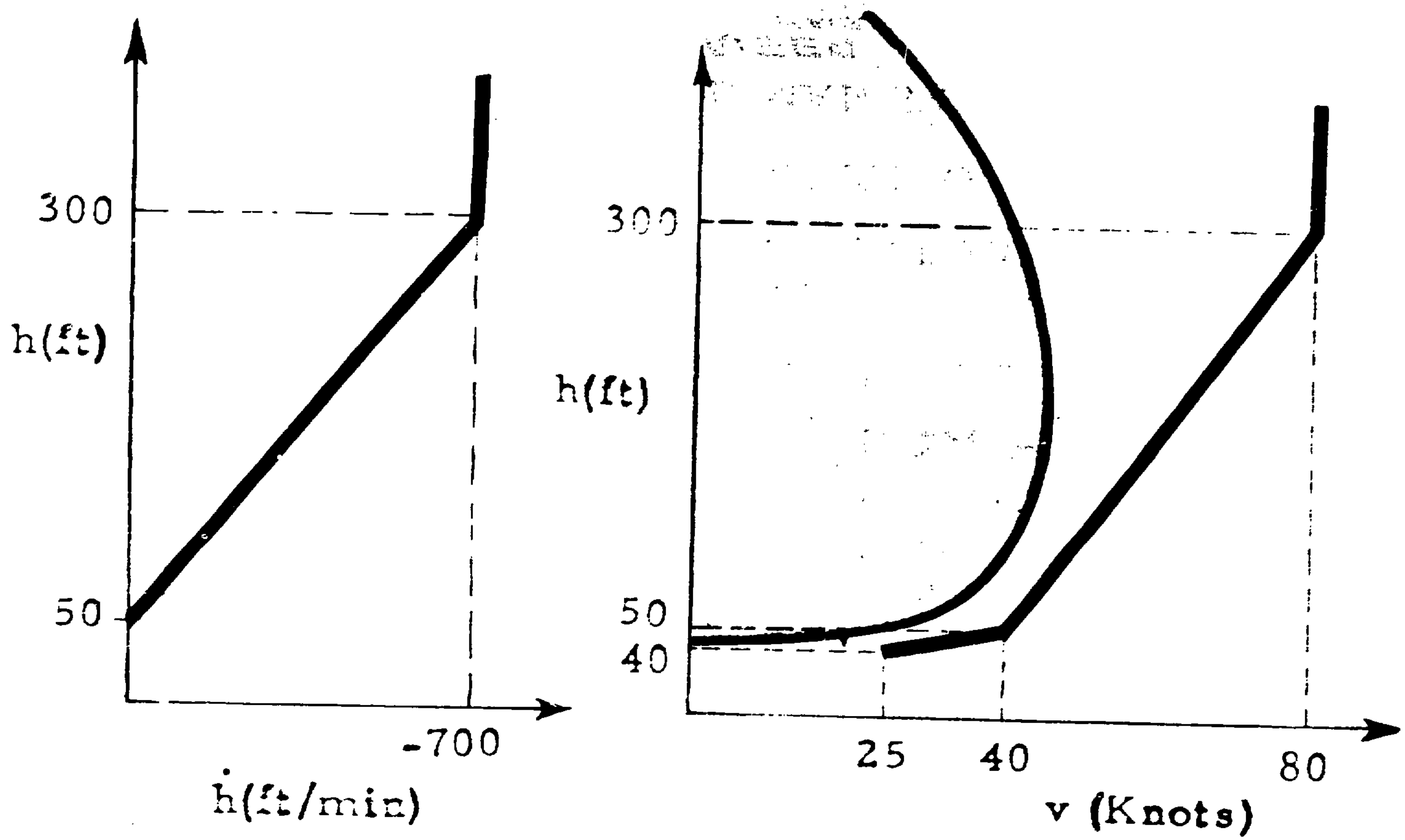


GLIDE SLOPE MODE

ENERGY REDUCTION CURVE

KAISER AEROSPACE & ELECTRONICS

SLIDE 2.



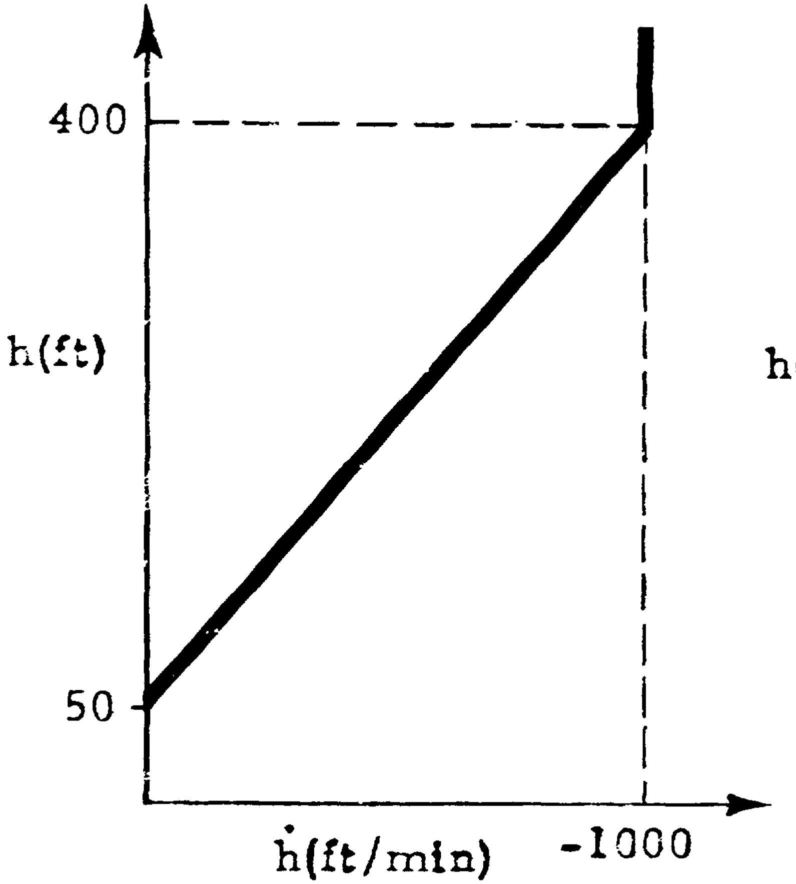
NORMAL 5° DESCENT MODE

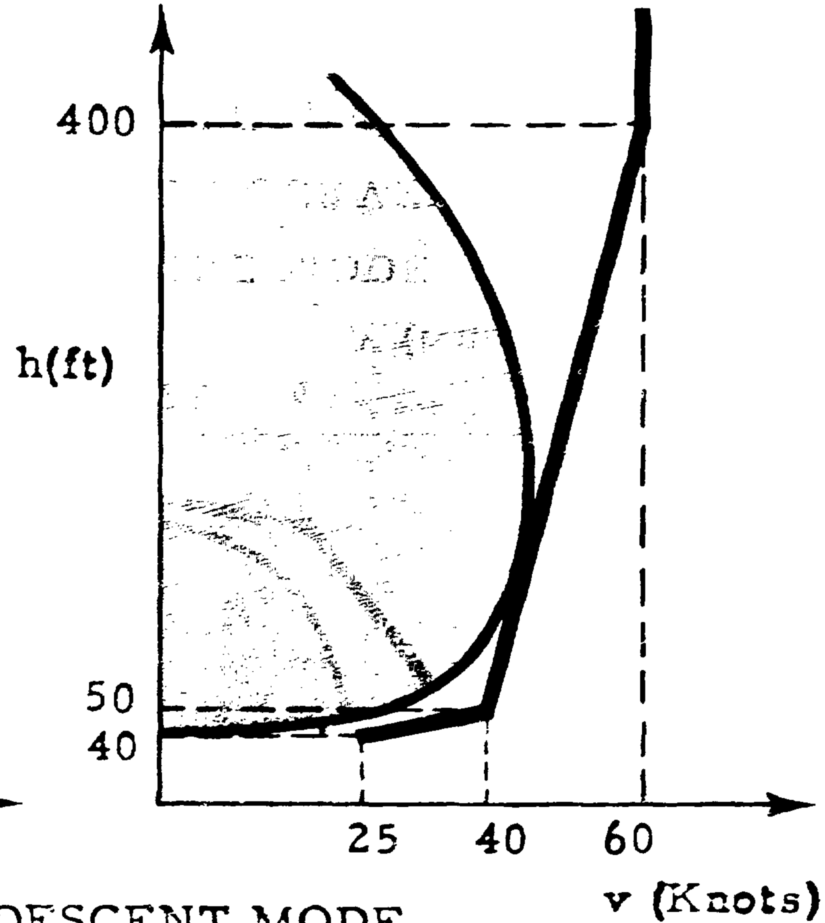
ENERGY REDUCTION CURVES

OH-6A DEAD MAN'S CURVE

KAISER
AEROSPACE &
ELECTRONICS

SLIDE 3.





STEEP 10° DESCENT MODE

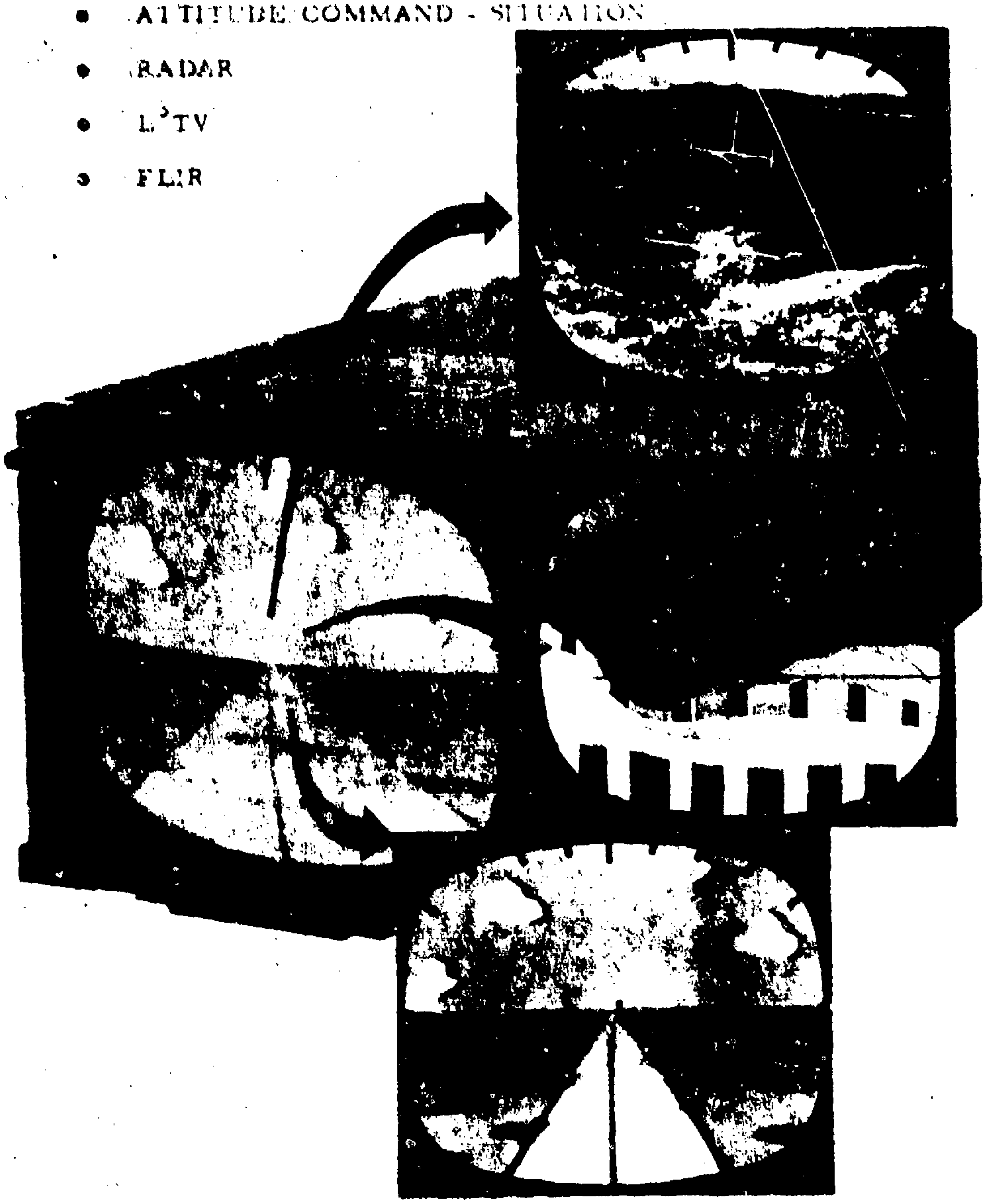
ENERGY REDUCTION CURVES

OH-6A DEAD MAN'S CURVE

KAISER AEROSPACE & ELECTRONICS

SLIDE 4.

- ATTITUDE COMMAND - SITUATION
- RADAR
- L³TV
- FLIR

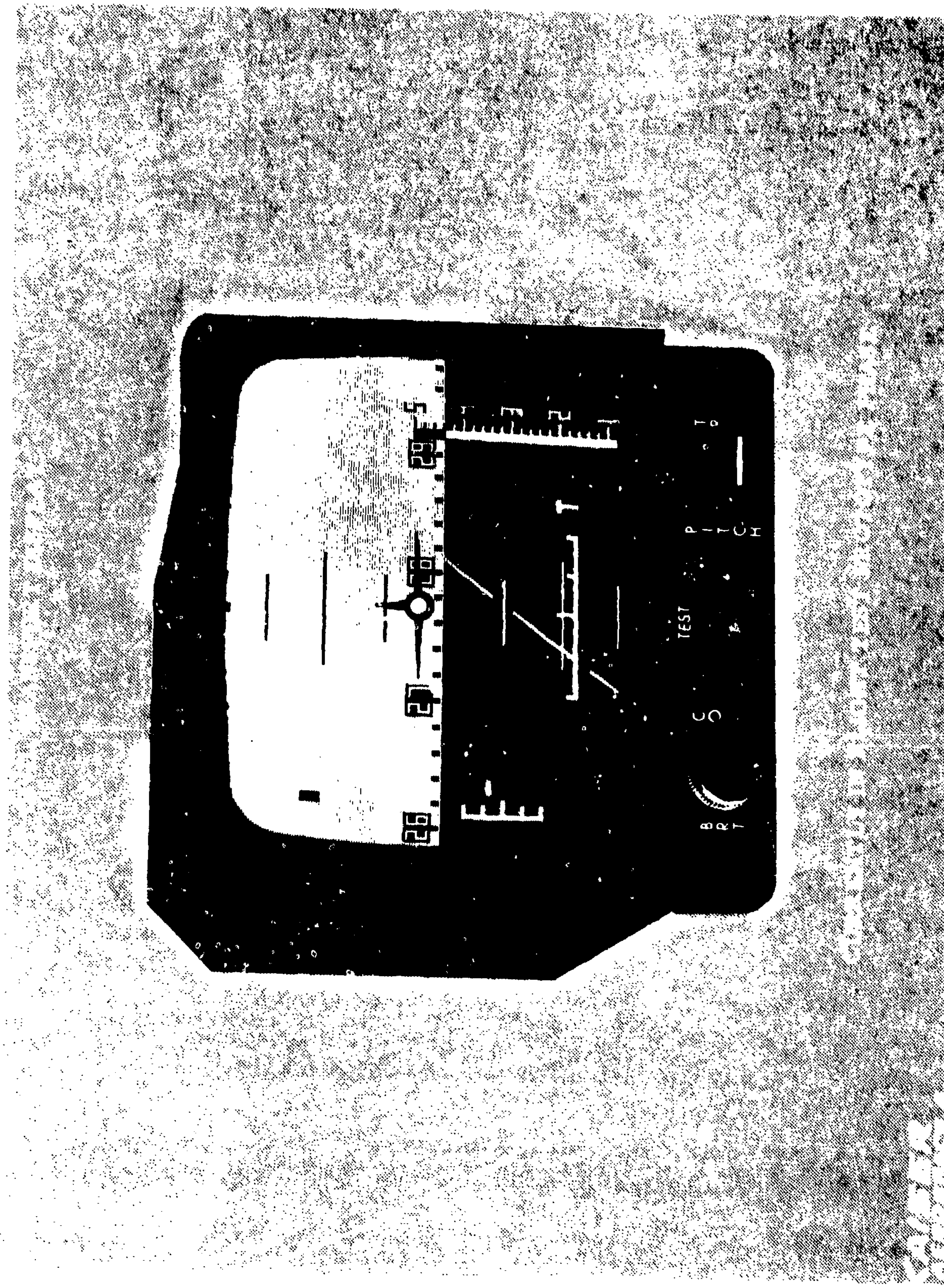


TIME PERIOD [illegible]

QTY PRODUCED [illegible]

KAISER AEROSPACE & ELECTRONICS

SLIDE 5.



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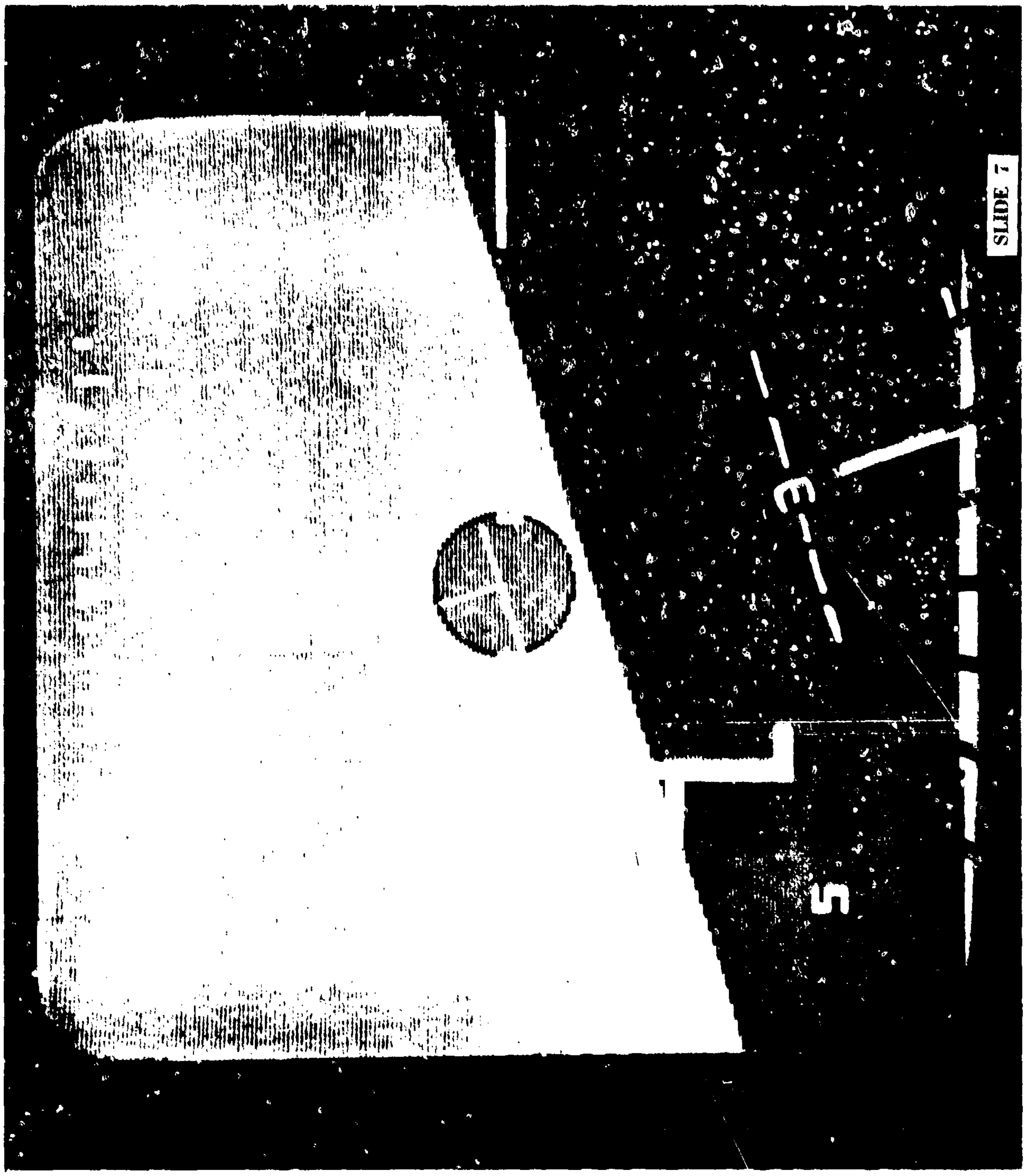
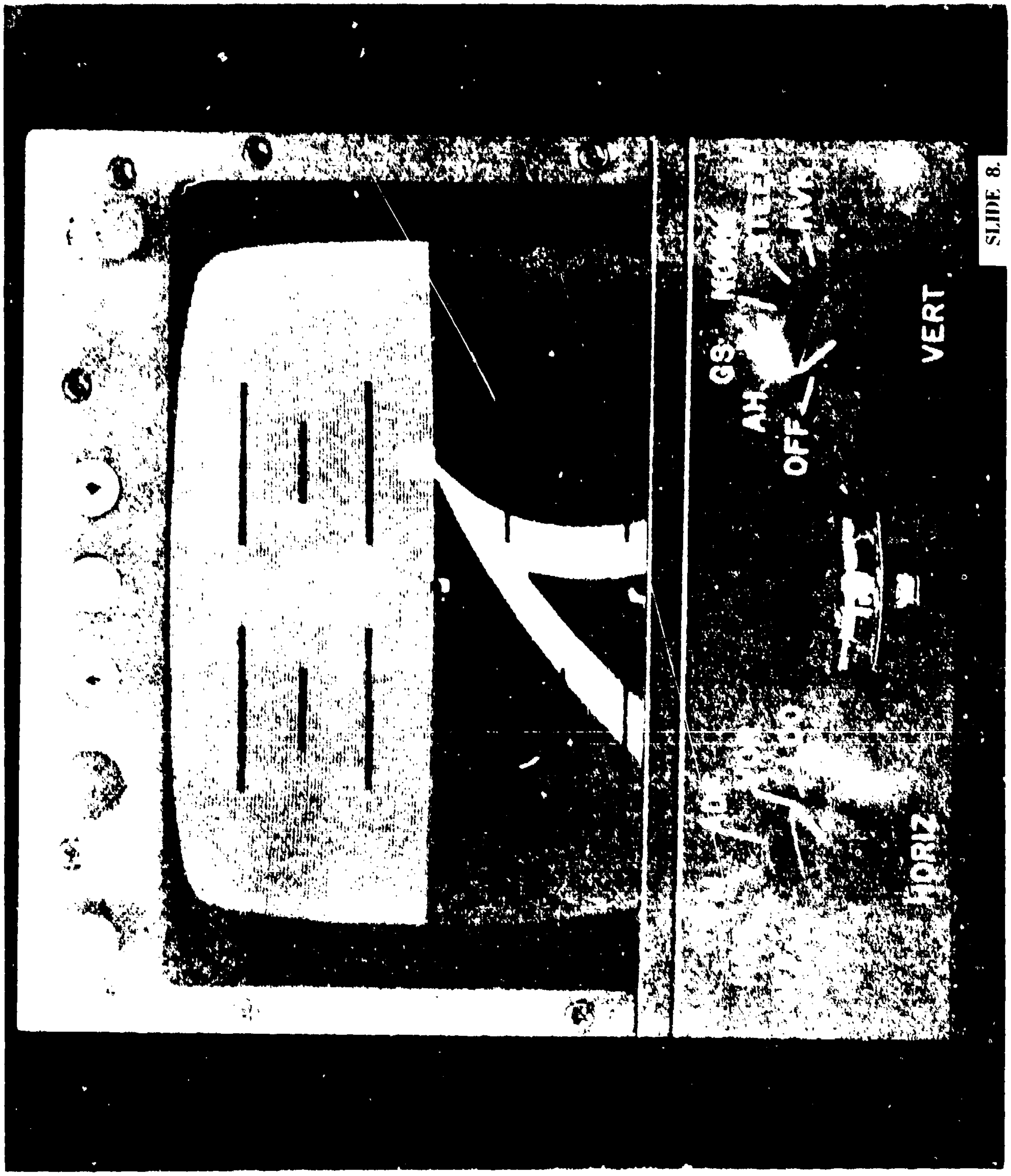
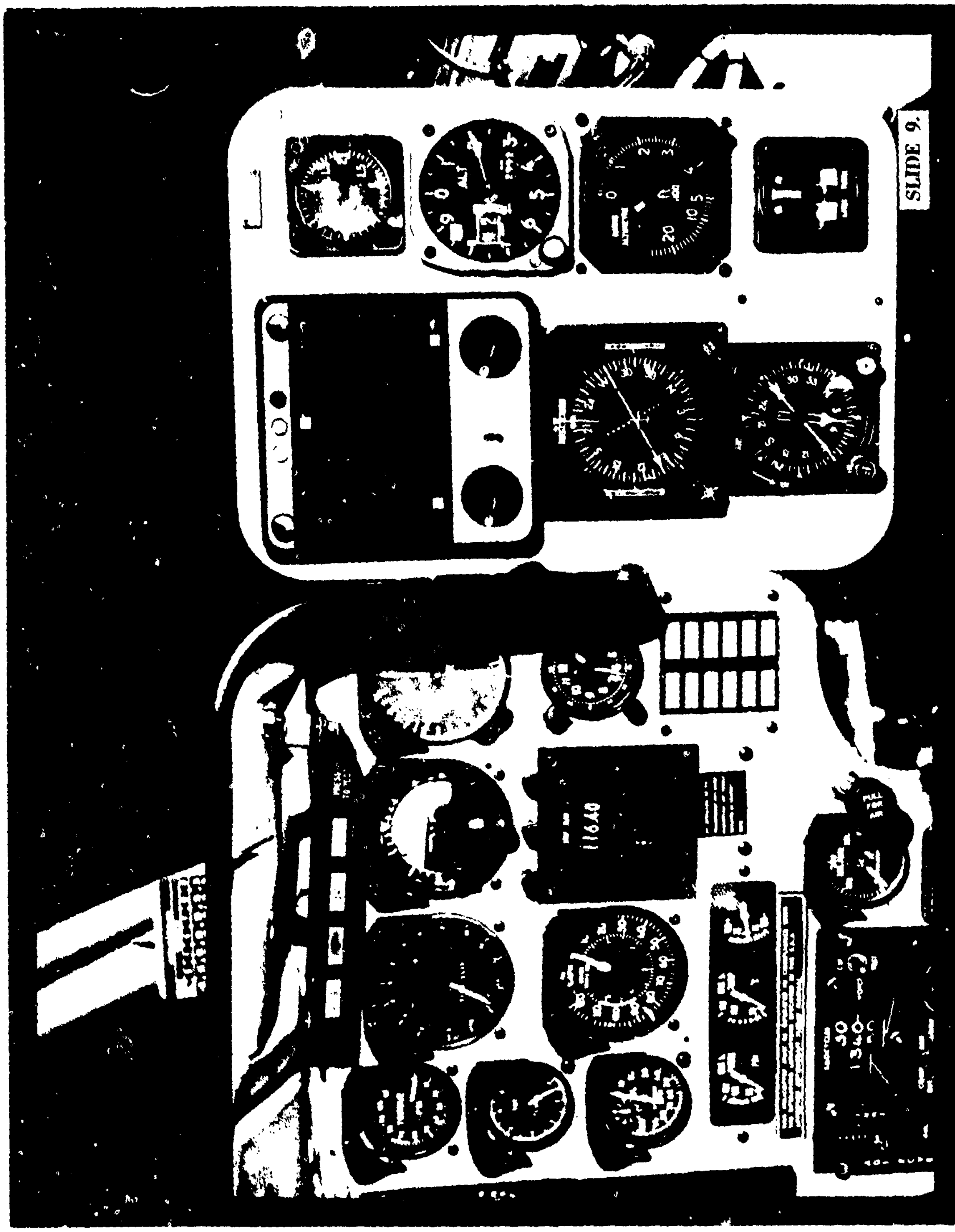

SLIDE 7


SLIDE 8.
GS
AH
OFF
VERT
HORIZ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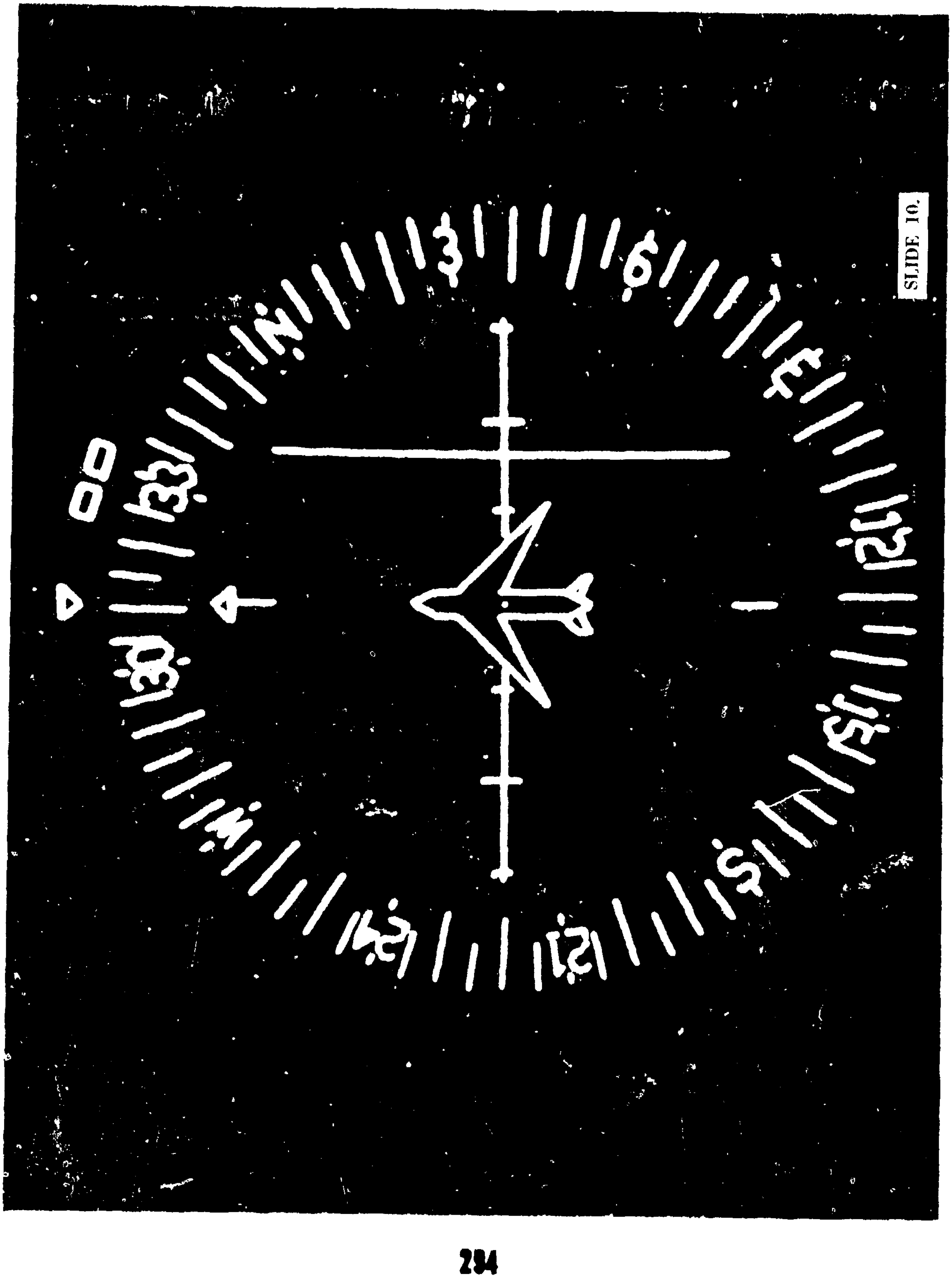
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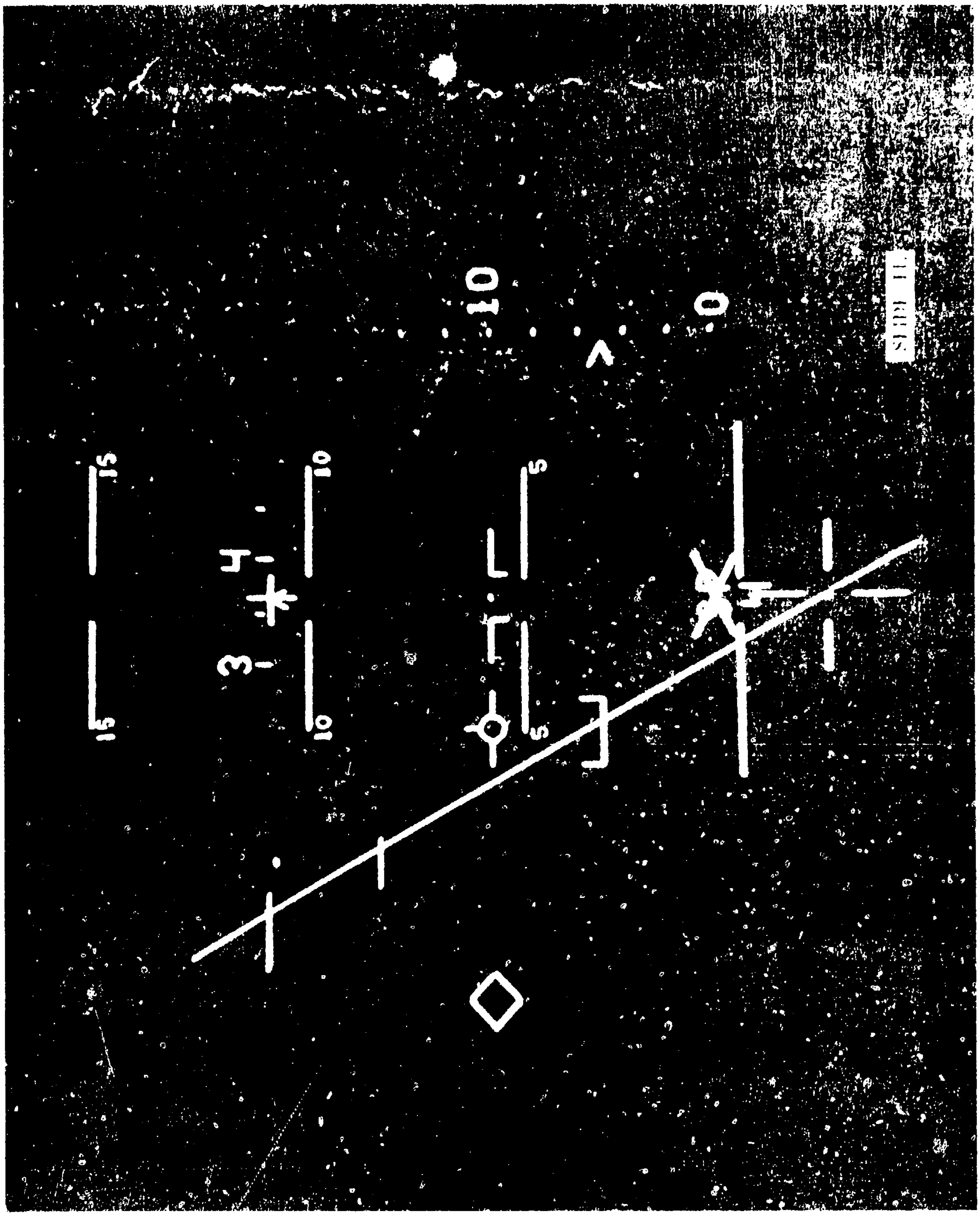

10
0
15
10
5
3
4
5
10
15

SUMMARY

- COMPUTER REQUIRED
- THREE CUES REQUIRED
- TECHNOLOGY IS HERE
- CRT PROVIDES GROWTH AT NO PENALTY PLUS SENSOR DISPLAY CAPABILITY

KAISER AEROSPACE & ELECTRONICS

SLIDE 12.

MR. HATCHER: Thank you, Phil.

Next we have John Dietrich of Sperry Flight Systems Division. John is Senior Marketing Representative in the Military Marketing Department, and is responsible for the developing of the Sperry helicopter command instrumentation system. Mr. Dietrich's experience includes design of space power systems and more recently developing instrument requirements and hardware for the Model 347, CH-47, UH-1 and LOH aircraft. John:

JOHN P. DIETRICH
SPERRY RAND

The command instrument system (CIS) that I will be speaking about is the system developed under contract for the Aerial Scout program.

Without re-explaining the system components to the extent that MAJ Smith did yesterday, I would like to briefly review the two key components which make the CIS an important tool in the tactical role and then discuss tactical concepts.

First slide, please (slide 1)

The controller, shown here, has been designed to provide command flexibility in the helicopter tactical environment. Note that the pilot may select command modes in vertical speed, airspeed, and heading hold in the total absence of active ground navigation or positioning aids, and can use these to relieve basic pilot workload in favor of mission-oriented work. Of prime importance to the tactical operation of CIS is the capability to make use of battlefield navigation aids such as FM, ADF, and TACNAV.

Next slide, please (slide 2)

The selectable vertical speed indicator (VSI) shown here is the key to vertical speed management in the tactical approach. Again, in the absence of any ground navigation aid, the pilot selects a vertical descent rate appropriate to his desired descent angle and is commanded to make control motions accordingly. High angle/decelerating tactical approaches result. As further testing proceeds, we hope to show commanded autorotational capability using this feature in conjunction with commanded airspeed hold.

Slide off, please

Before we proceed into the tactical concepts discussion, everyone should understand that we are not attempting to make military doctrine here. CDC, or now TRADOC, makes doctrine and we at Sperry offer the information that follows only as food for thought based on our extensive knowledge of command instrument systems and the tactical concept knowledge we have assimilated through contact with the military during development and testing.

Next slide, please (slide 3)

The first area that we feel CIS can offer definite advantages in combat is in an area that is often overlooked, *ie*, basic pilotage or dead reckoning. We hope to prove by test that dead reckoning accuracy can be significantly improved by use of CIS and some knowledge of wind conditions at takeoff. The relatively short mission legs flown by helicopters makes improved accuracy DR a useful tactical tool. It is useful in VFR and night operations, especially to the 211-hour

Fort Rucker graduate who might tend to let his heading and airspeed wander a bit while performing other mission duties. It is interesting to note that DR is a vital function in sophisticated area navigation systems which automatically go into DR when radio navigation information fails or is intermittent.

Next slide, please (slide 4)

The CIS instruments and controls are shown as they would be used in this DR mode.

Next slide, please (slide 5)

Probably the most common navigation aid available on the battlefield is the field communication FM radio. CIS, using the integrated FM steering display for long-term guidance and the heading hold mode for short-term stability, provides greatly improved accuracy to FM homer navigation. Use of high angle/decelerating approaches to letdown further reduces pilot workload and provides an improved degree of safety.

Next slide, please (slide 6)

The FM homing tactical approach panel is shown in the FM navigation mode. (note error in slide – heading bug)

Next slide, please (slide 7)

A concept which must be considered in the tactical situation makes use of any ADF beacons or commercial broadcast stations operating in the area as navigation aids. When properly instrumented, the ADF data is flown in a manner very similar to CONUS VOR with pilot commands displayed in an identical manner. The value of commanded ADF is a function of the basic ADF loop/receiver quality and of installation interference. We have had good performance with ADF in certain test installations and marginal performance in others. We intend to continue to work on the hardware problem until we solve it because of the high value commanded ADF can have in the tactical role.

Next slide, please (slide 8)

Note that ADF raw data appears on HSI and ADI exactly as VOR data and commands appear. A poor ADF loop/receiver will oscillate, causing "S"-turning. Roll stability is not the only problem, basic ADF drift is!

Next slide, please (slide 9)

Army TACNAV, as we understand it, will be a combination of LORAN positioning and a scanning beacon-type ILS. The LORAN system in the aircraft computes the coordinates of the aircraft from received data and the pilot inserts the coordinates of his destination. The CIS derives steering and range data from this information and provides steering command as well as altitude and airspeed hold command. The CIS commands the letdown in the same manner with the tactical ILS as with a commercial ILS, although probably at a much higher descent angle. In the absence of tactical ILS, a tactical approach without aids would be used. Pilot thinking workload is significantly reduced by use of CIS, a degree of added safety is provided, and the pilot can spend more of his time on the mission. This is especially true at single pilot missions in the smaller helicopters.

Next slide, please (slide 10)

This is the panel in the TACNAV bracket format with TACNAV positioning showing termination in tactical ILS approach.

Next slide, please (slide 11)

We have talked about high angle/decelerating tactical approaches all though this discussion, and rightfully so, because of the tremendous value of this command concept to the tactical role. I will review this slide in detail to show theory and to point out the future test work we anticipate is required to definitize command parameters. Much work has been done studying high angle approaches and we do not intend to "re-invent the wheel" theory-wise. We will, however, optimize the CIS for the highest possible angle/deceleration combinations, even to engine failure autorotation situations if that proves feasible. Consenus at present is that 9 to 12 degrees will be maximum for IFR letdowns. We will, I feel, be pleasantly surprised when we see the results of full 3-axis command letdowns at high angles with commanded deceleration. Please consider this portion of the discussion again if you have the opportunity to fly the CIS this week.

Next slide, please (slide 12)

This slide illustrates panel conditions during the deceleration letdown. Note rising runway, airspeed indications, and descent rate. It is much safer to be near touchdown in an organized manner than fighting the airframe for control during the last critical moments of the approach.

This brings us to future plans. We hope to continue development and conduct tests in two additional areas in the near future.

Next slide, please (slide 13)

This slide illustrates panel conditions nea touchdown at 10 to 20 knots with the CIS. Improvements to the extended airspeed sensor will be required before the touchdown can be made much slower than 20 knots, but even 20 knots is not a prohibitively high "skid-on" speed. We have purchased improved sensors for airspeed and plan flight tests in the near future.

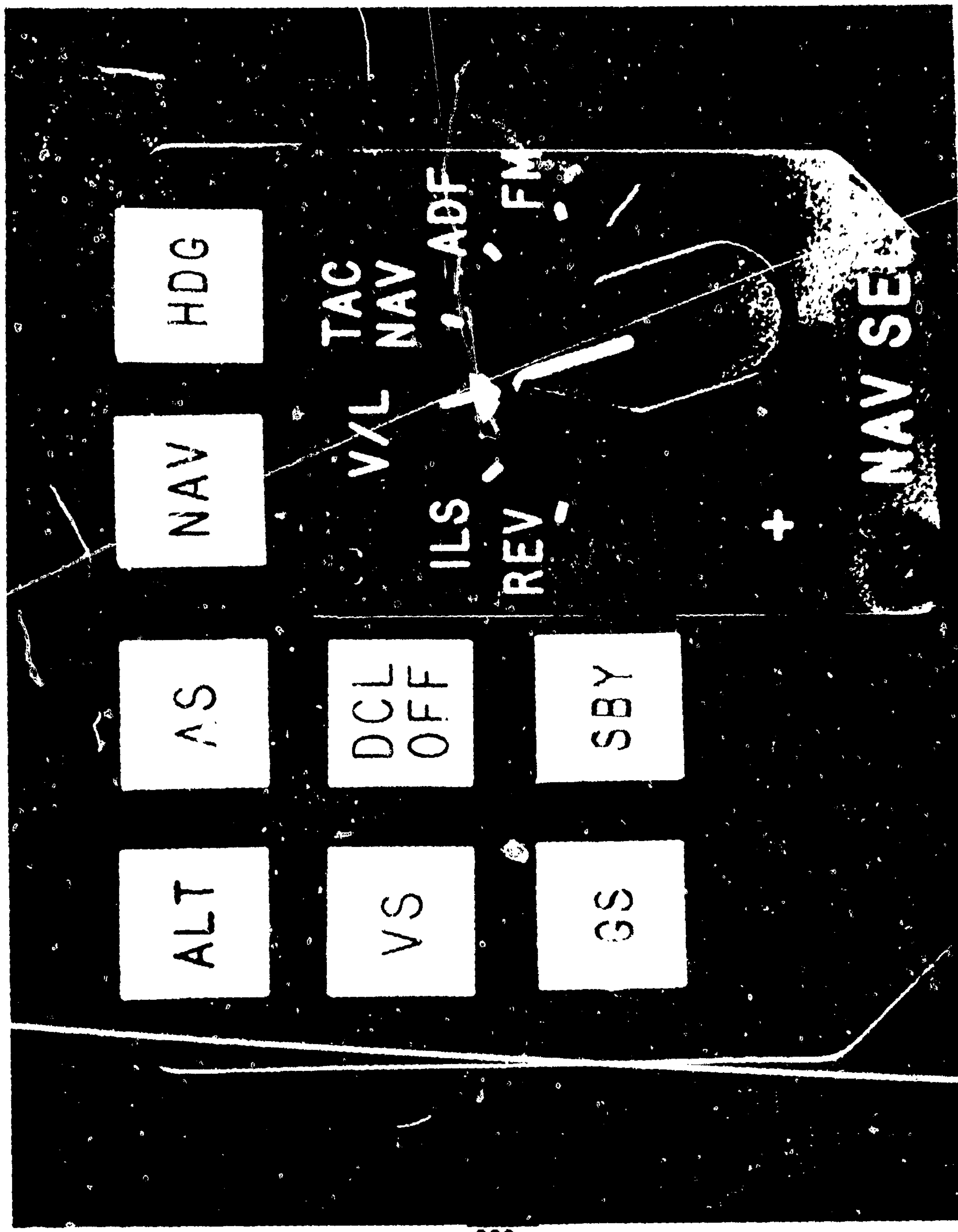
Next slide, please (slide 14)

This panel depicts the situation that will exist when the improved power management system is added to the CIS. At present there is no reliable closed loop feedback term to prevent the CIS from commanding over-boost of the helicopter turbine. A development program is under way at Sperry to provide and test such a system in one of the existing CIS aircraft. The power management command, when obeyed, will prevent over-boost turbine operation anywhere within the operational range of the aircraft, even with varying loads. This will be a boon to maintenance also, in that engine damage will be reduced.

Next slide, please (slide 15)

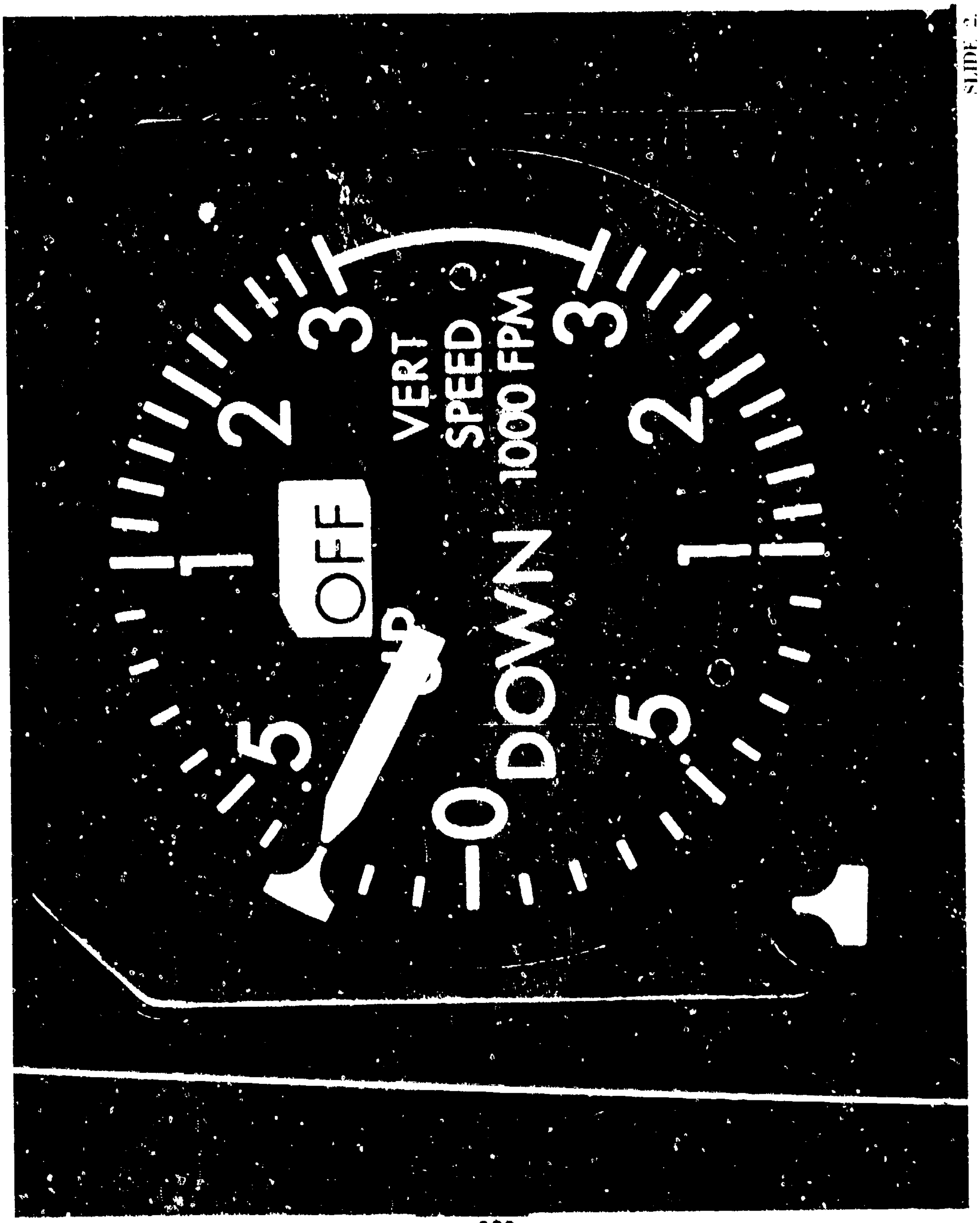
As this slide shows, happiness is a satisfied command instrument system.

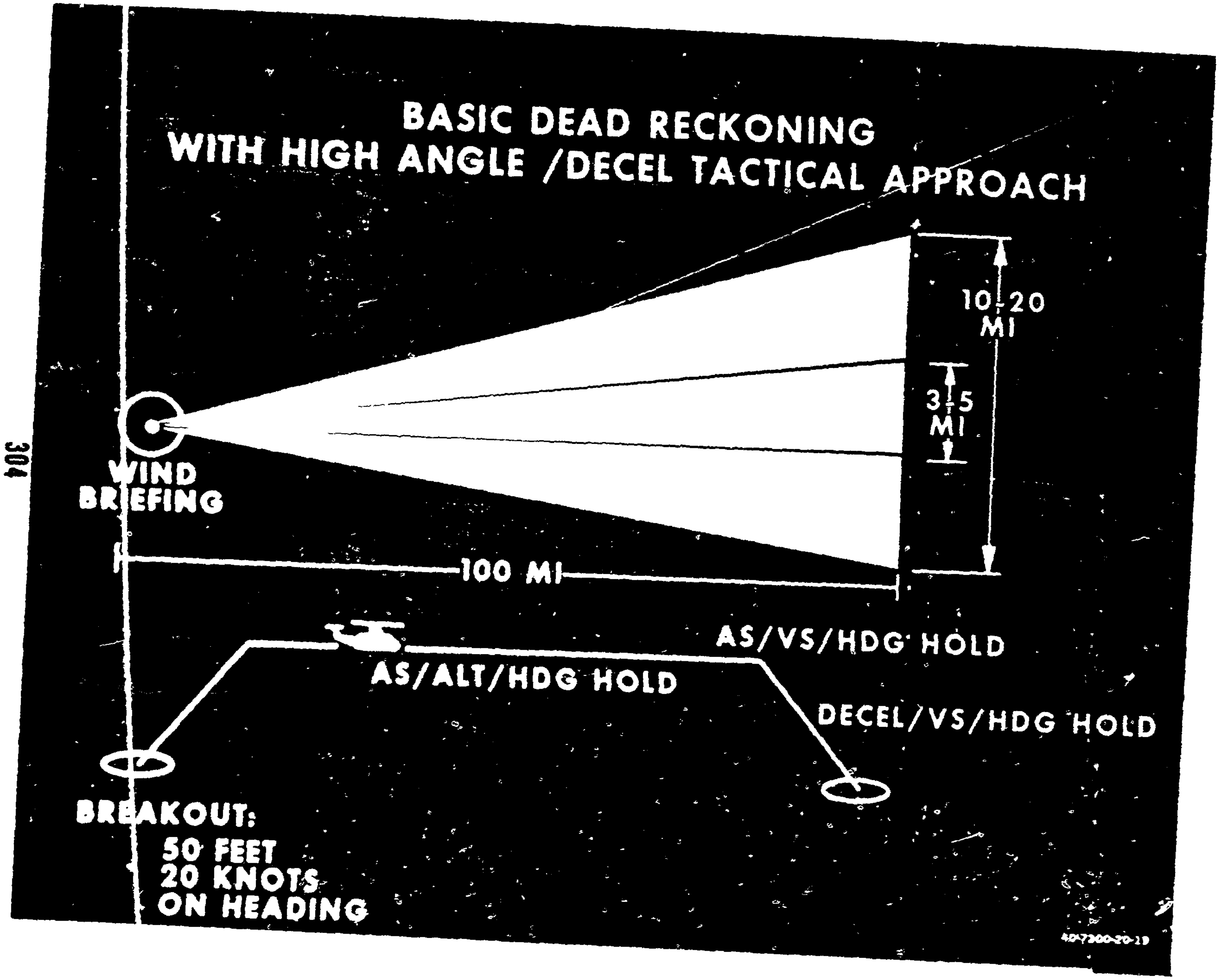
Thank you.



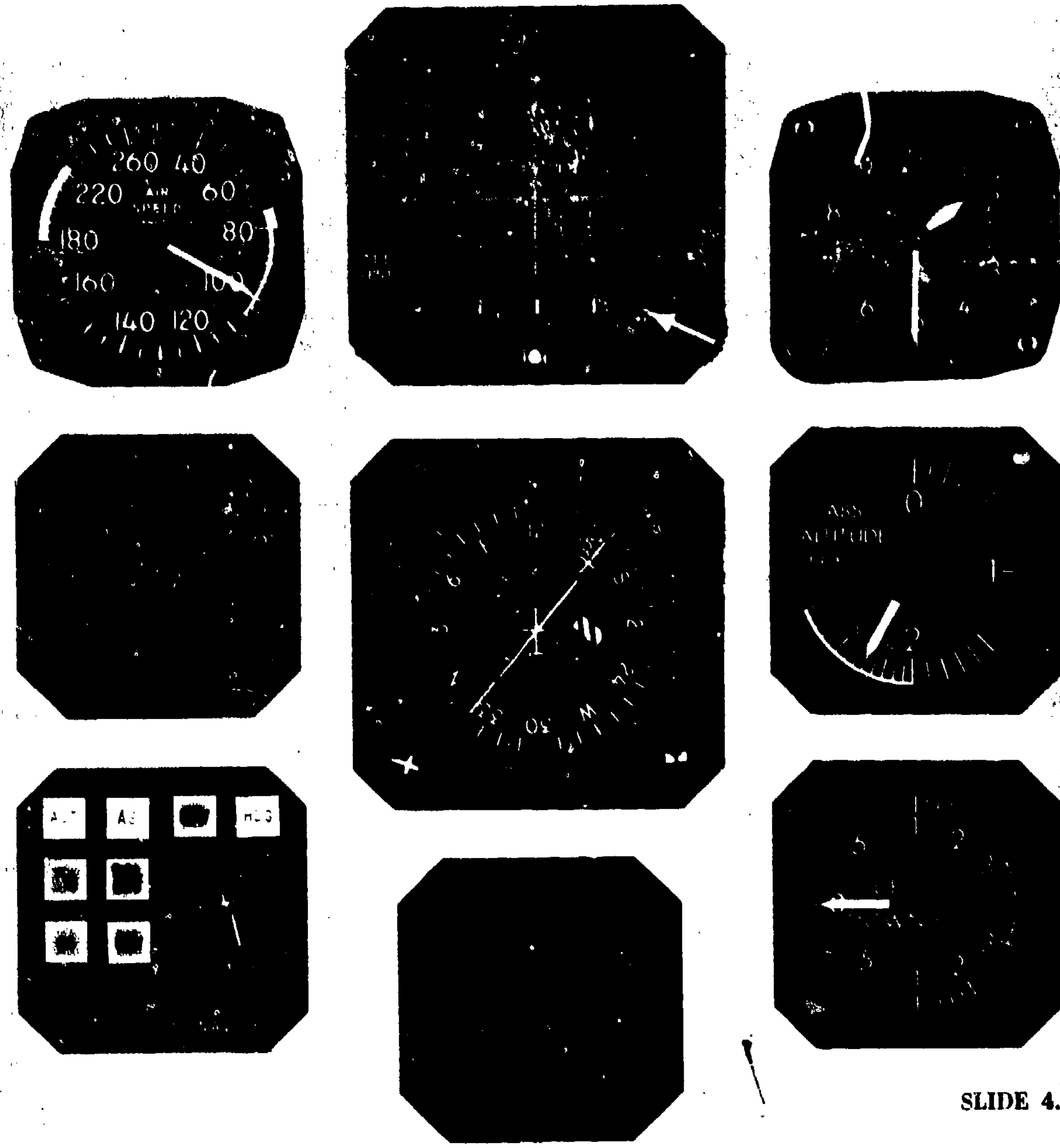
SLIDE 1.

SLIDE

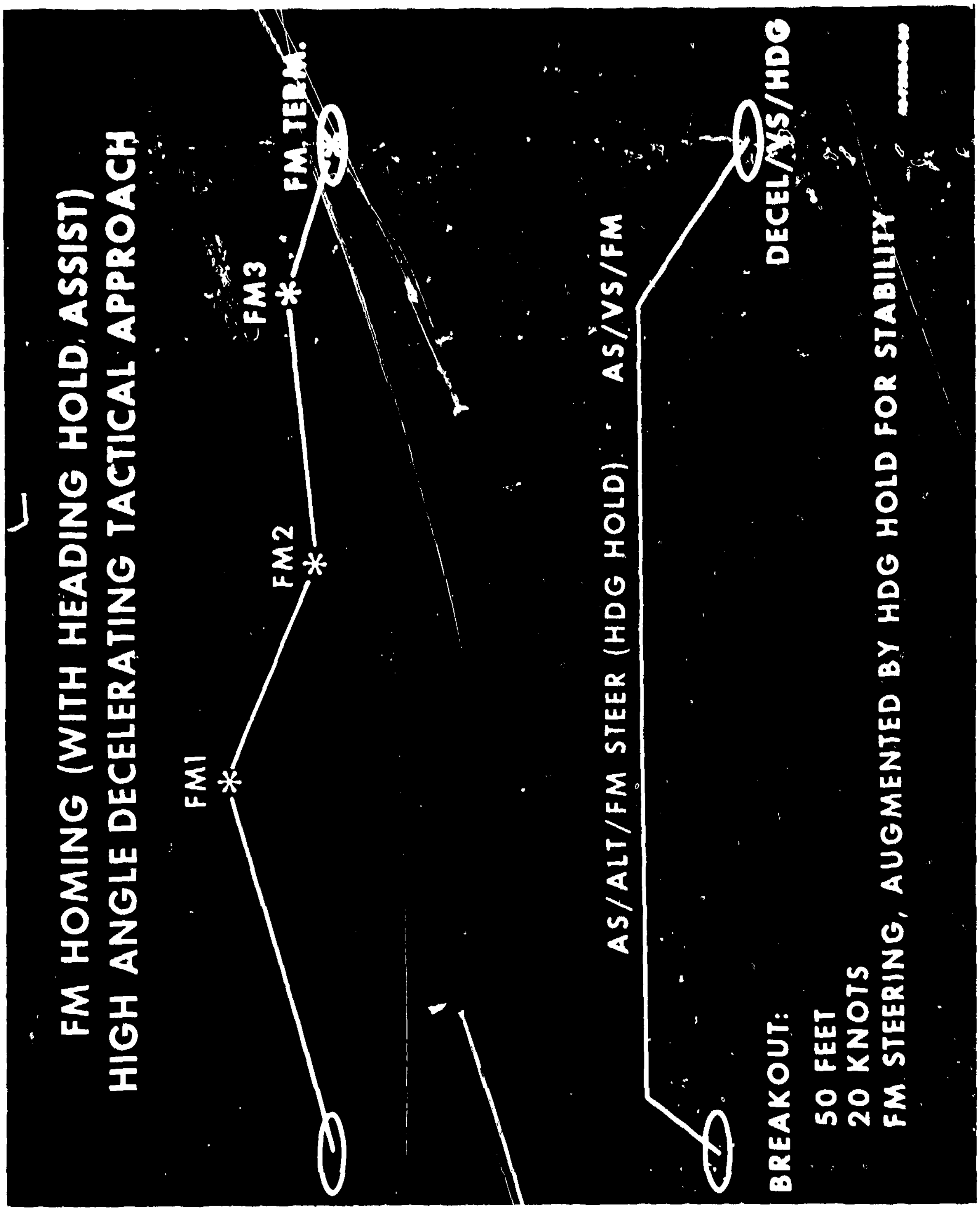



BASIC DEAD RECKONING
WITH HIGH ANGLE /DECEL TACTICAL APPROACH
10-20 MI
3-5 MI
WIND BRIEFING
100 MI
AS/VS/HDG HOLD
AS/ALT/HDG HOLD
DECEL/VS/HDG HOLD
BREAKOUT:
50 FEET
20 KNOTS
ON HEADING
AD-7300-20-19

SLIDE 3.

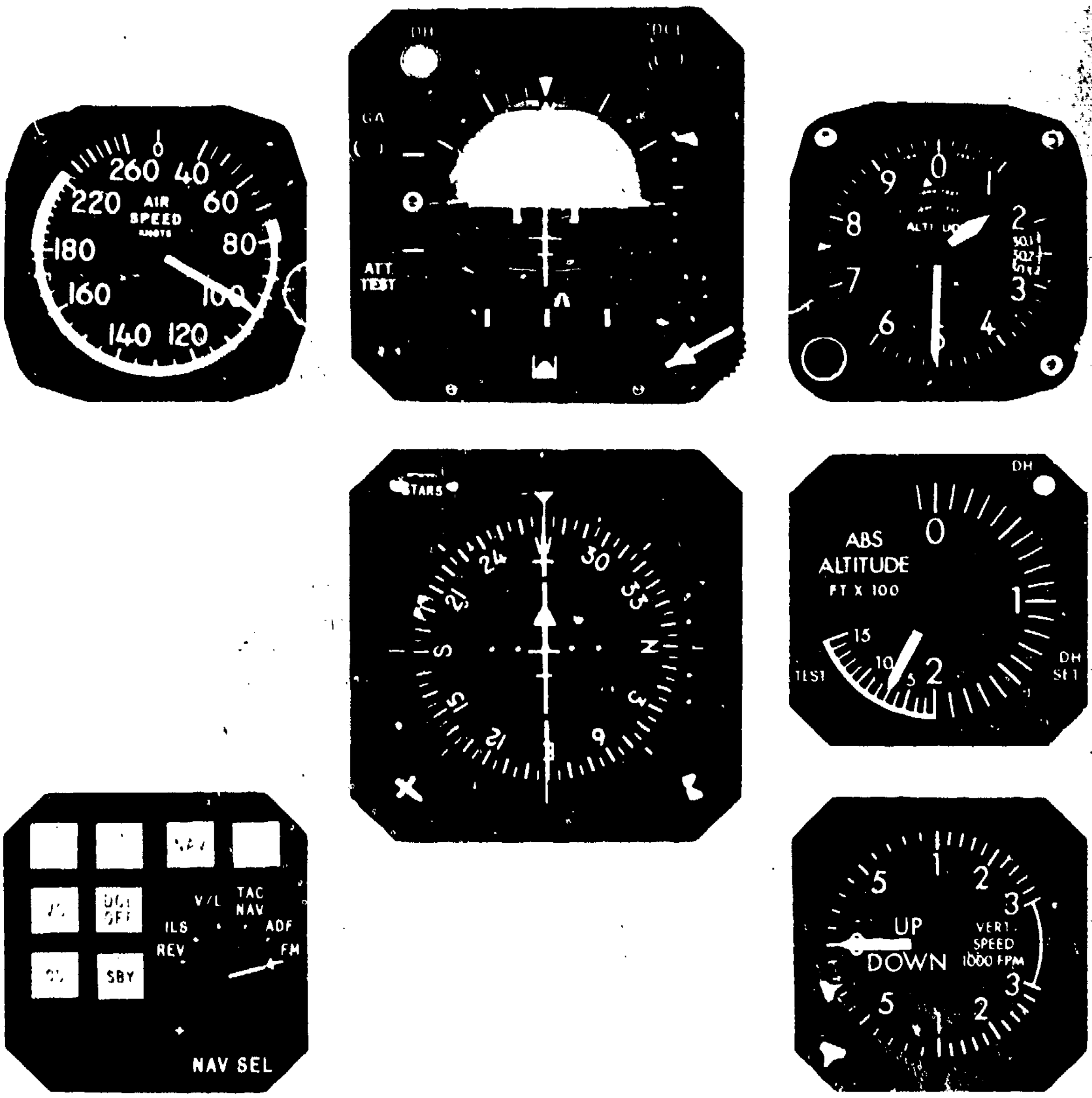


SLIDE 4.

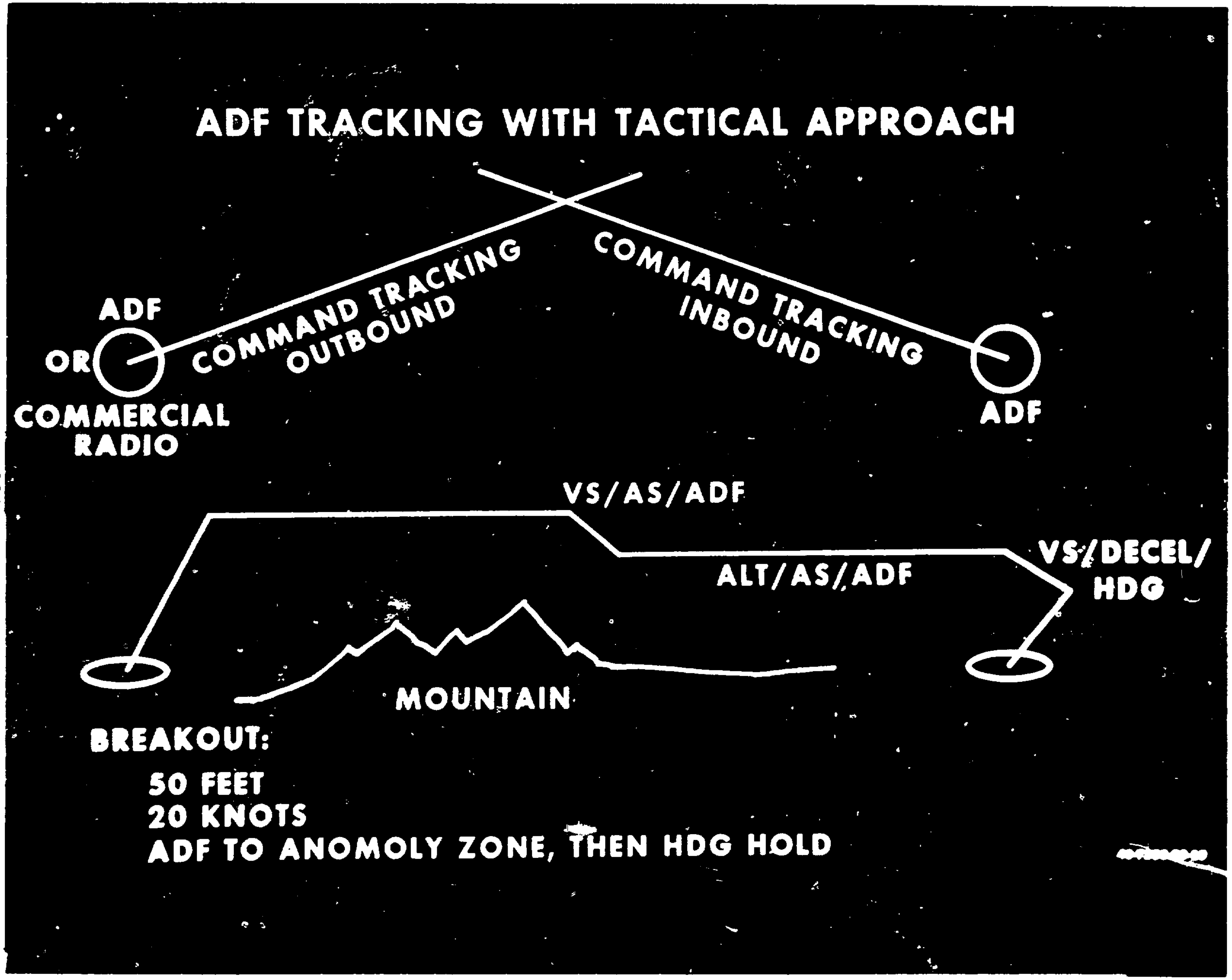


FM HOMING (WITH HEADING HOLD ASSIST)
HIGH ANGLE DECELERATING TACTICAL APPROACH
FM1
FM2
FM3
FM TERM.
AS/ALT/FM STEER (HDG HOLD)
AS/VS/FM
DECEL/AS/HDG
BREAKOUT:
50 FEET
20 KNOTS
FM STEERING, AUGMENTED BY HDG HOLD FOR STABILITY

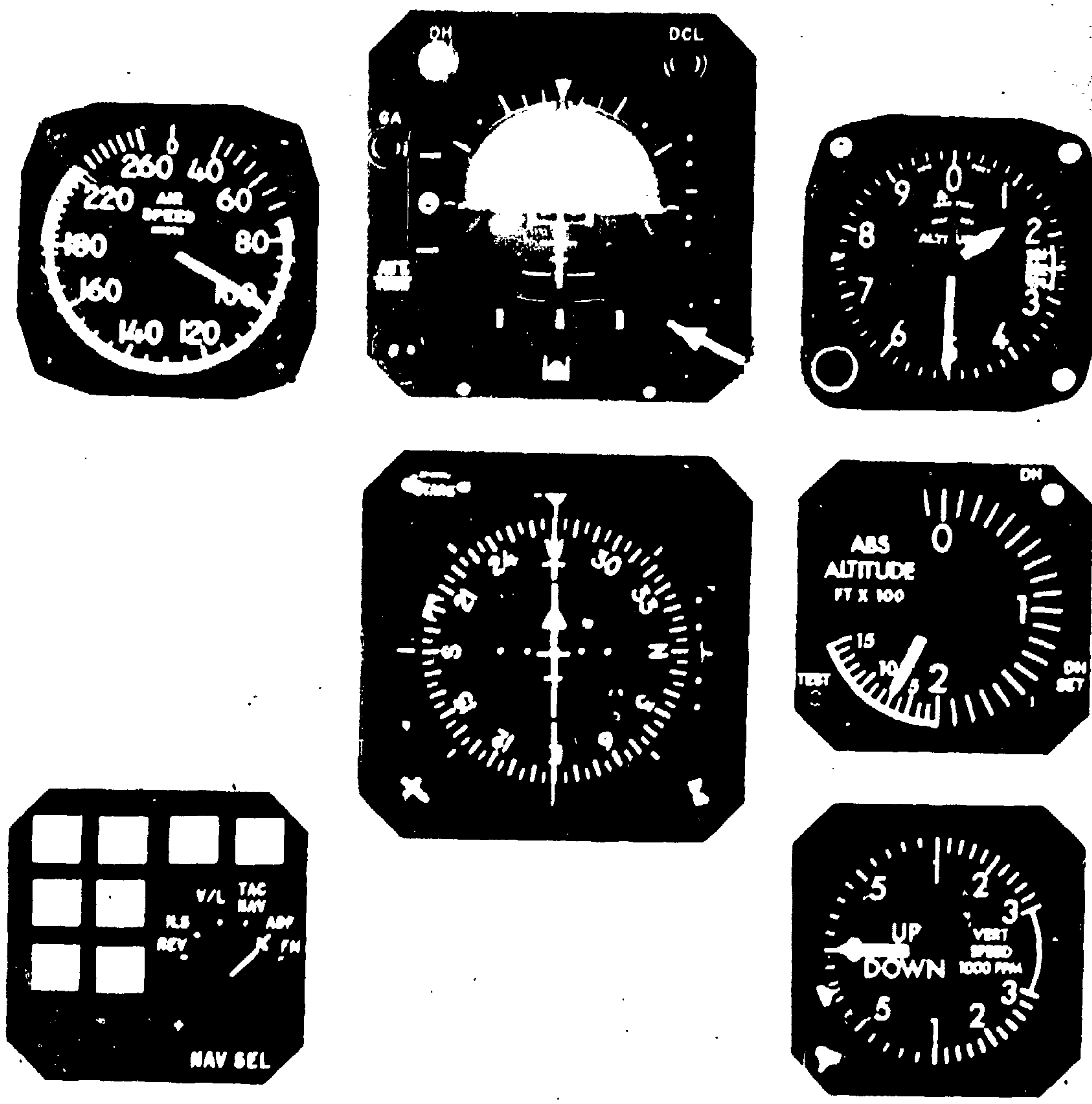
SLIDE 5.


AIR SPEED KNOTS
260
40
60
220
80
180
160
100
140
120
ATT TEST
ABS ALTITUDE
FT X 100
TEST
DH SET
DH
UP
DOWN
VERT. SPEED 1000 FPM
SBY
V/L
TAC NAV
ILS
ADF
REV
FM
NAV SEL

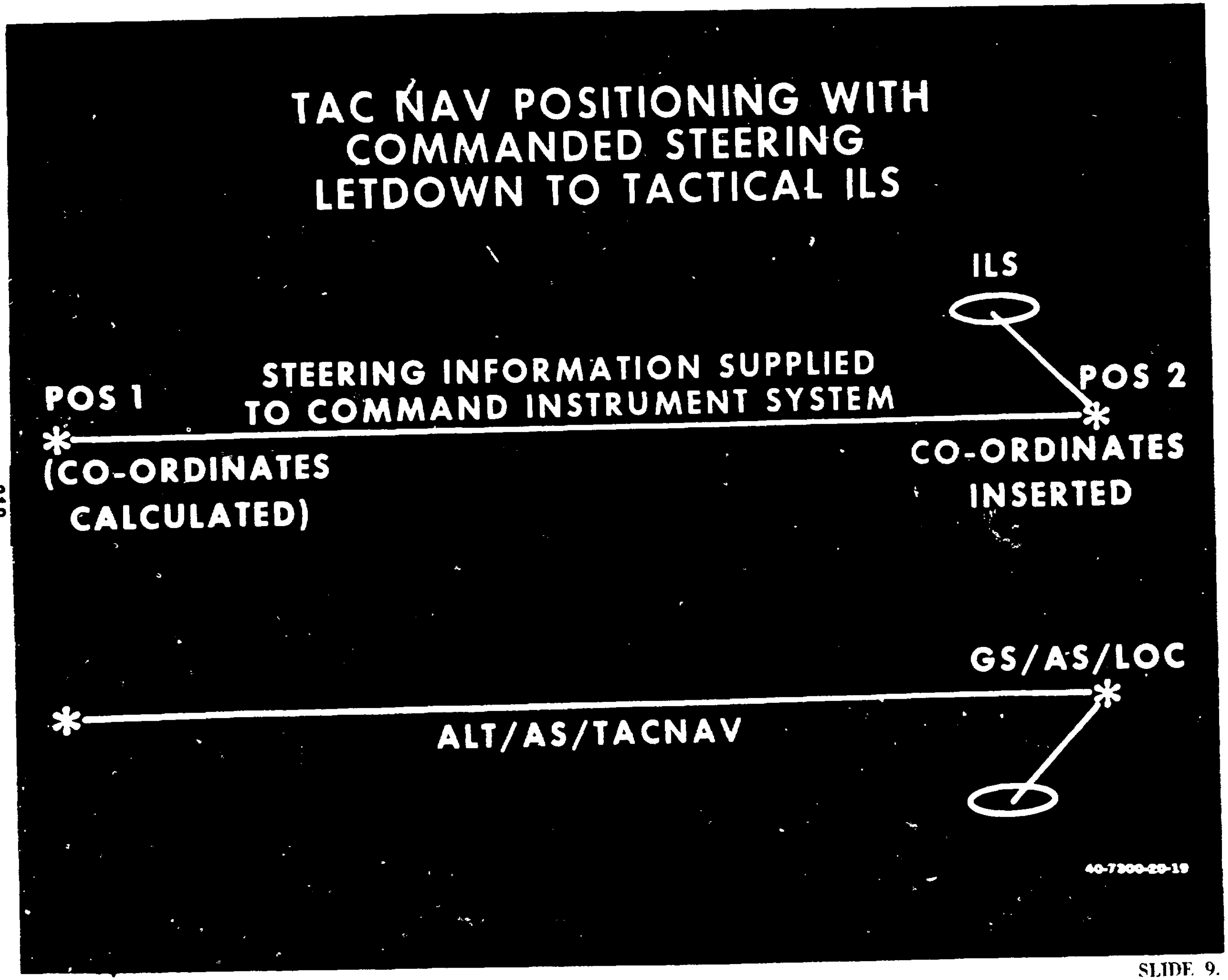
SLIDE 6.


ADF TRACKING WITH TACTICAL APPROACH
ADF
OR
COMMERCIAL RADIO
COMMAND TRACKING OUTBOUND
COMMAND TRACKING INBOUND
ADF
VS/AS/ADF
ALT/AS/ADF
VS/DECEL/ HDG
MOUNTAIN
BREAKOUT:
50 FEET
20 KNOTS
ADF TO ANOMOLY ZONE, THEN HDG HOLD

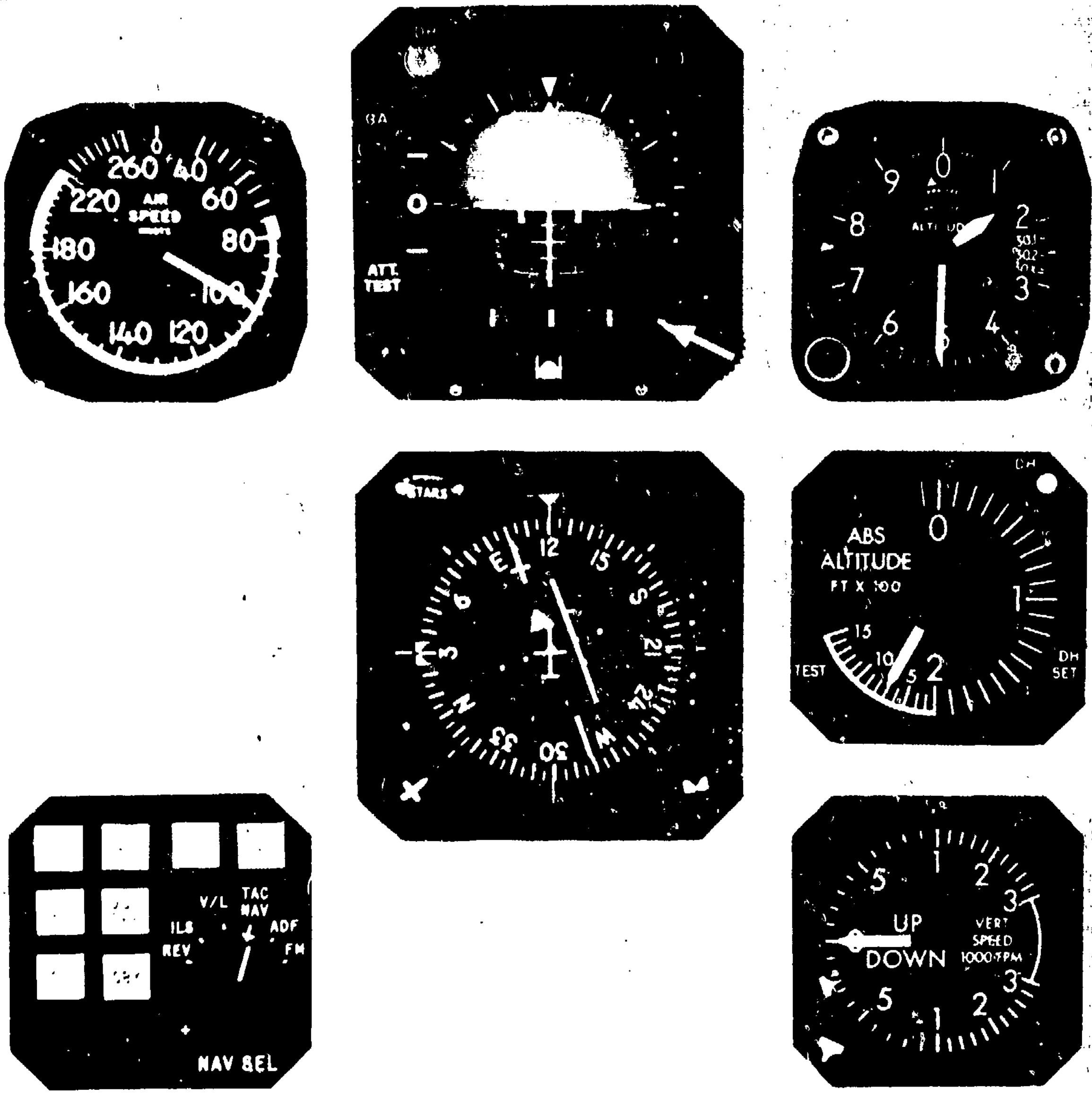
SLIDE 7.


AIR SPEED
DH
DCL
GA
ABS ALTITUDE
FT X 100
TEST
DH SET
UP
DOWN
VERT SPEED 1000 FPM
V/L
TAC NAV
ILS
REV
ADF
FM
NAV SEL

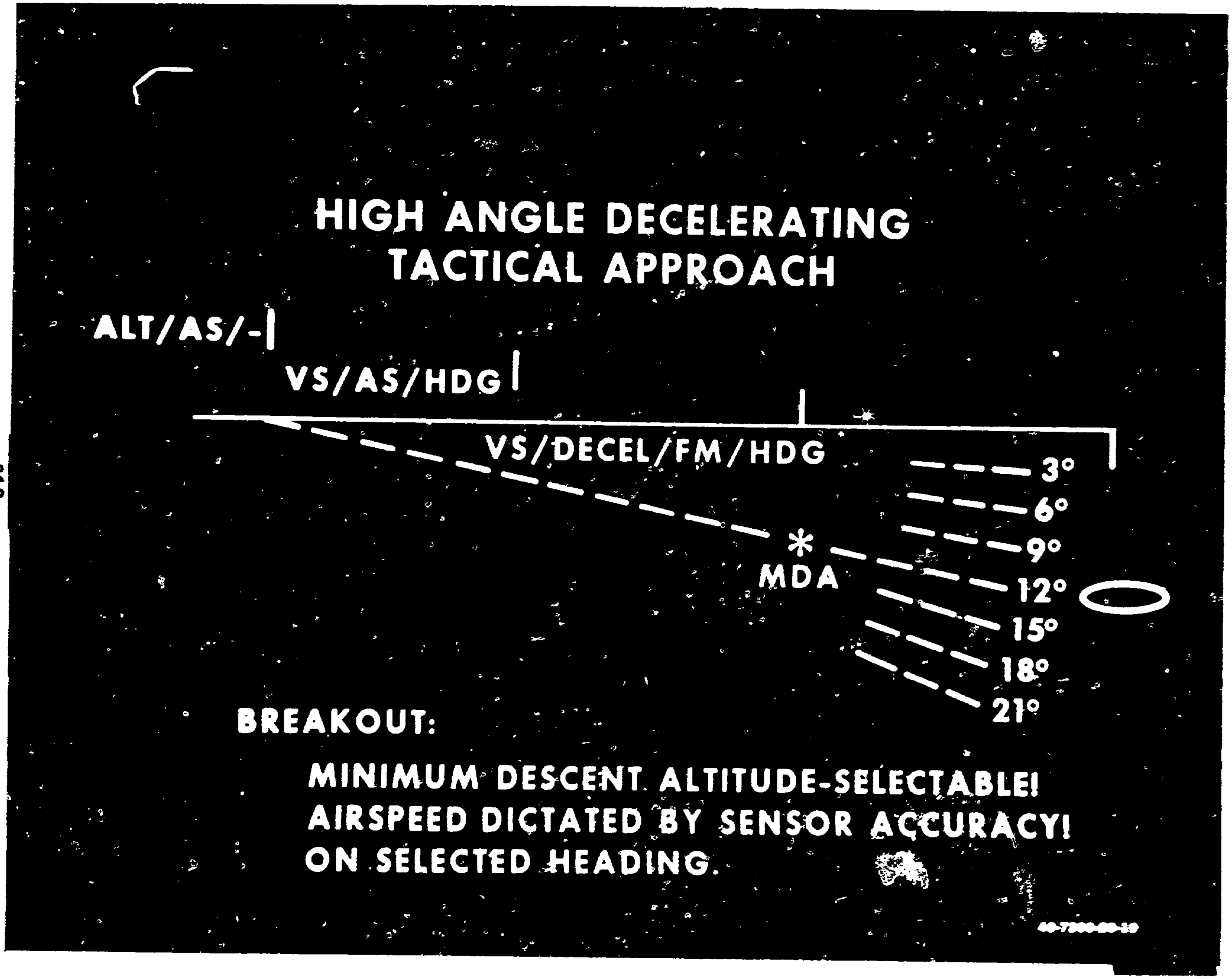
SLIDE 8.


TAC NAV POSITIONING WITH
COMMANDED STEERING
LETDOWN TO TACTICAL ILS
ILS
POS 1
STEERING INFORMATION SUPPLIED
TO COMMAND INSTRUMENT SYSTEM
POS 2
(CO-ORDINATES
CALCULATED)
CO-ORDINATES
INSERTED
GS/AS/LOC
ALT/AS/TACNAV
40-7300-29-19

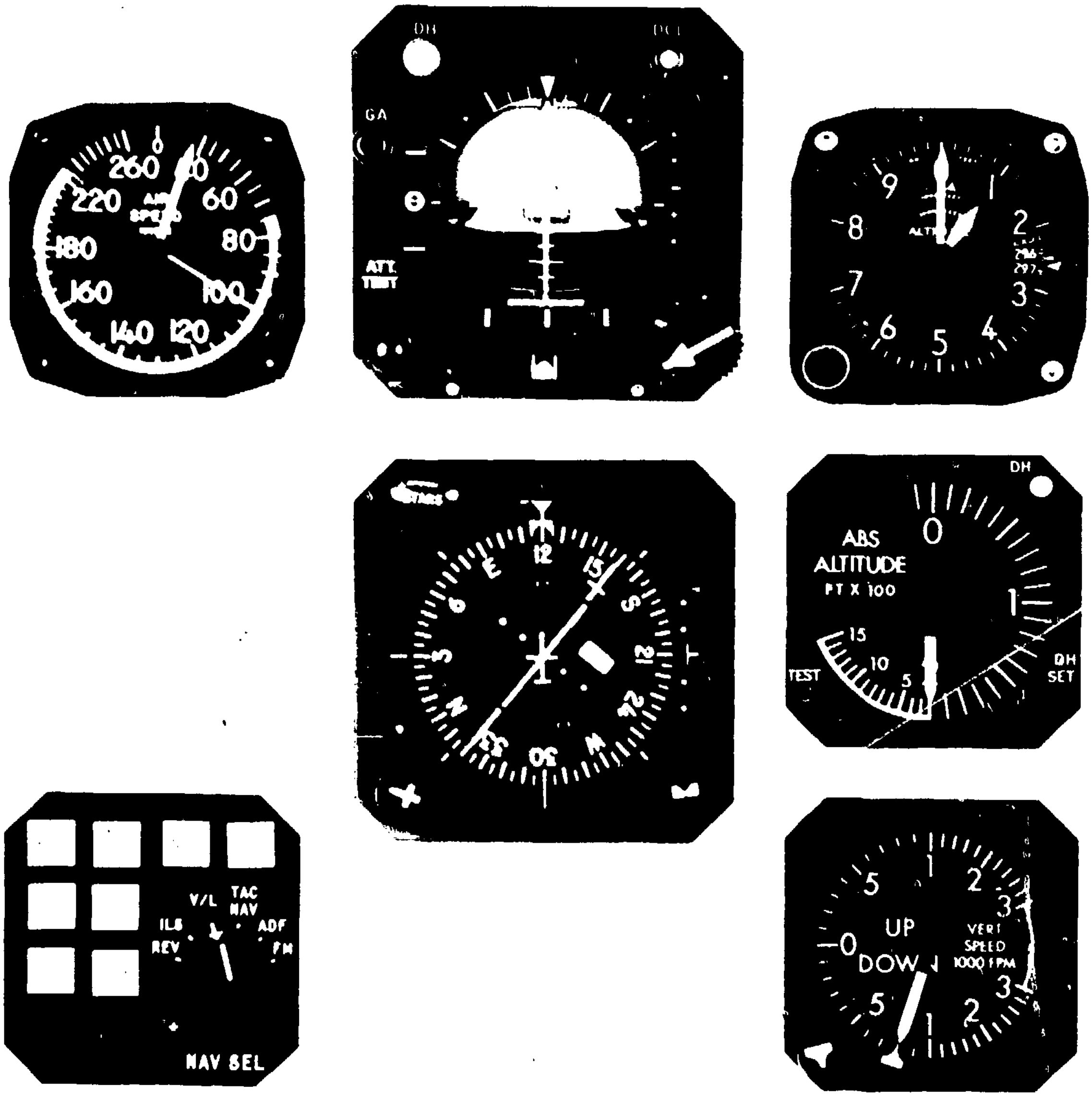
SLIDE 9.


AIR SPEED
ATT. TEST
ABS ALTITUDE
FT X 100
TEST
DH SET
UP
DOWN
VERT SPEED
1000 FPM
V/L
TAC NAV
ILS
REV
ADF
FM
NAV SEL

SLIDE 10.


HIGH ANGLE DECELERATING
TACTICAL APPROACH
ALT/AS/-
VS/AS/HDG
VS/DECEL/FM/HDG
3°
6°
9°
12°
15°
18°
21°
MDA
BREAKOUT:
MINIMUM DESCENT ALTITUDE-SELECTABLE!
AIRSPEED DICTATED BY SENSOR ACCURACY!
ON SELECTED HEADING.

SLIDE 11.


GA
ATT. TEST
DH
ABS ALTITUDE
FT X 100
TEST
DH SET
UP
VERT SPEED
1000 FPM
V/L
TAC NAV
ILS
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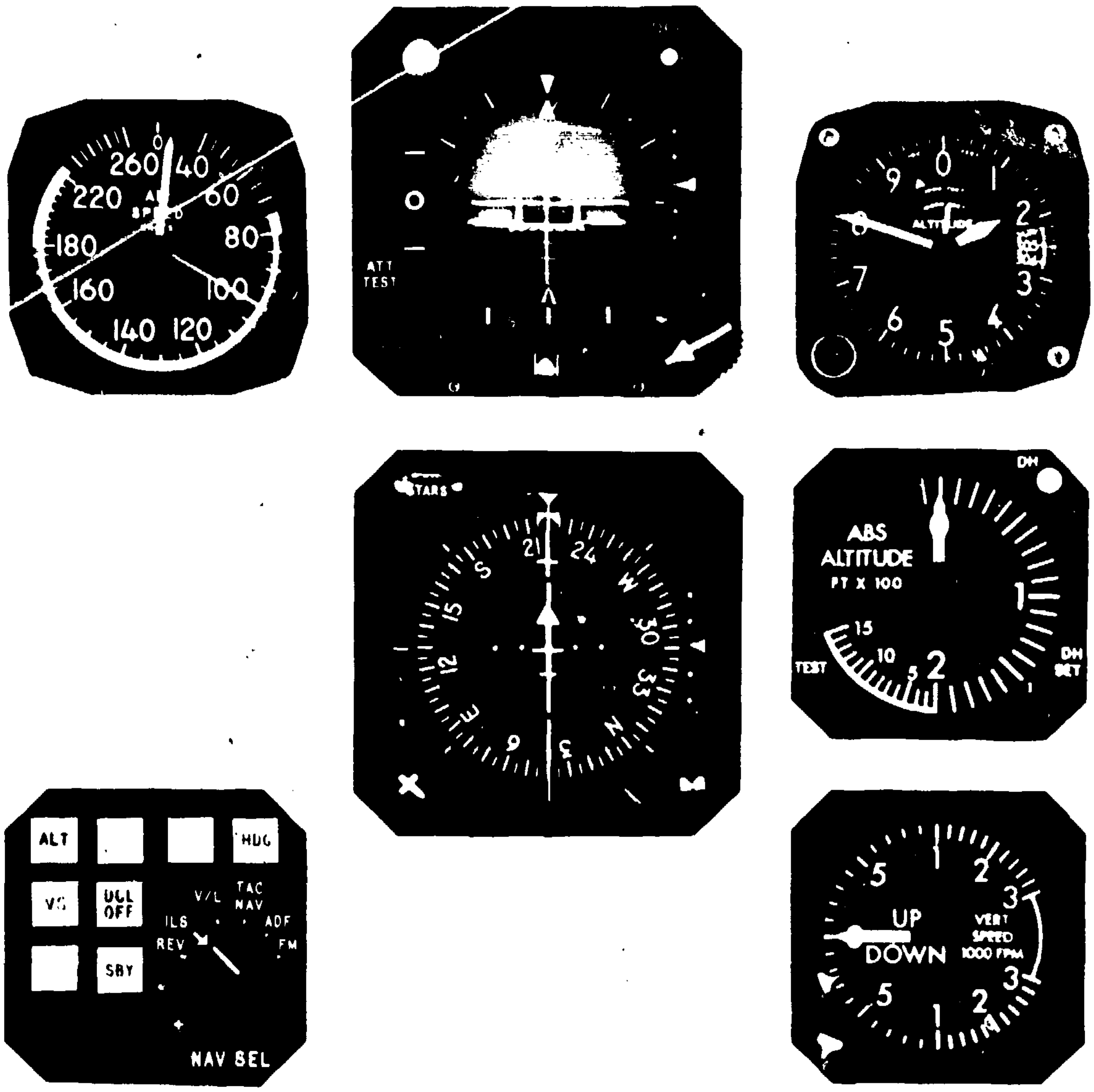
REV
FM
NAV SEL

SLIDE 12.



260
40
220
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UP
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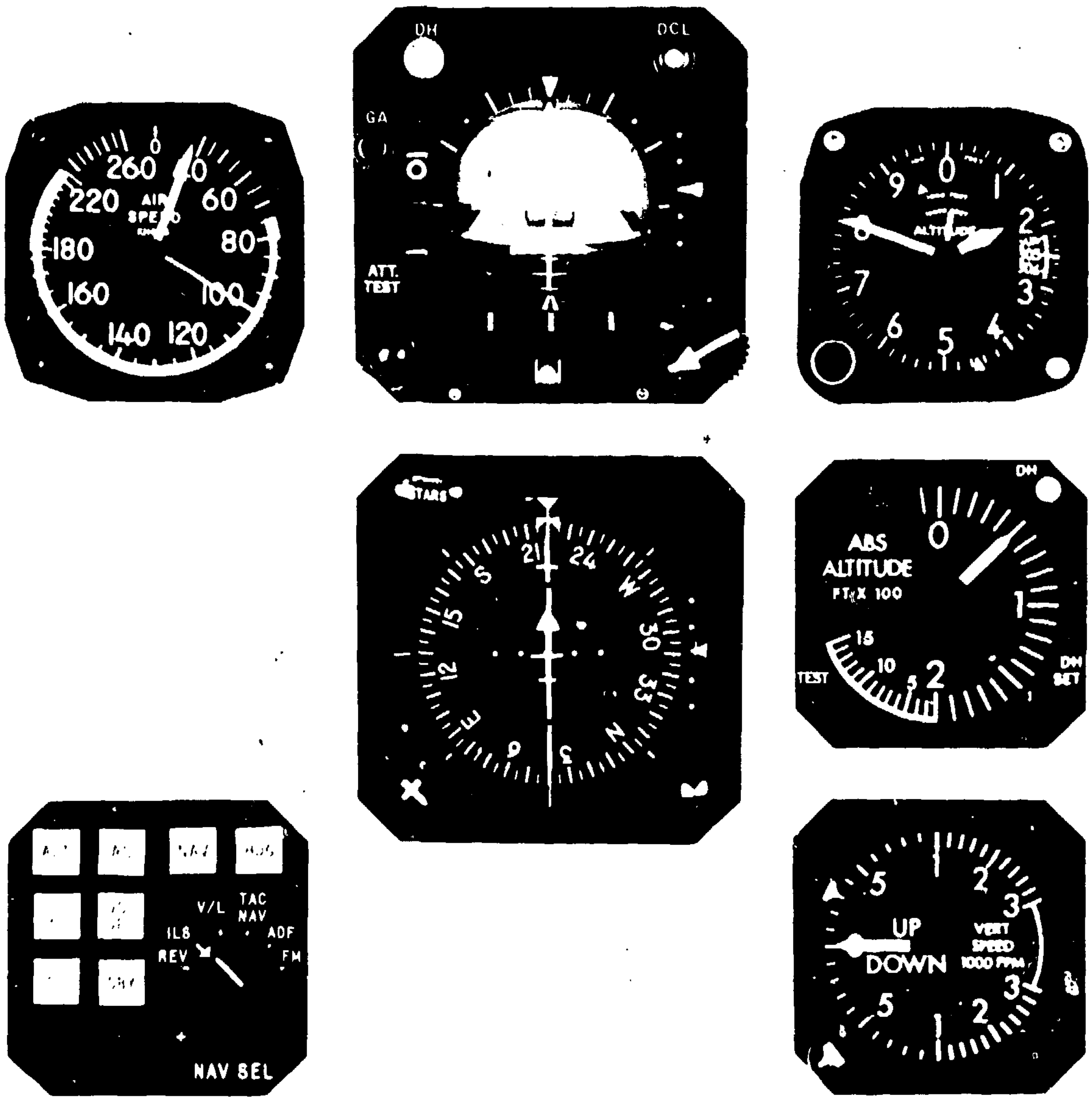
VERT
SPEED
1000 FPM

SLIDE 13.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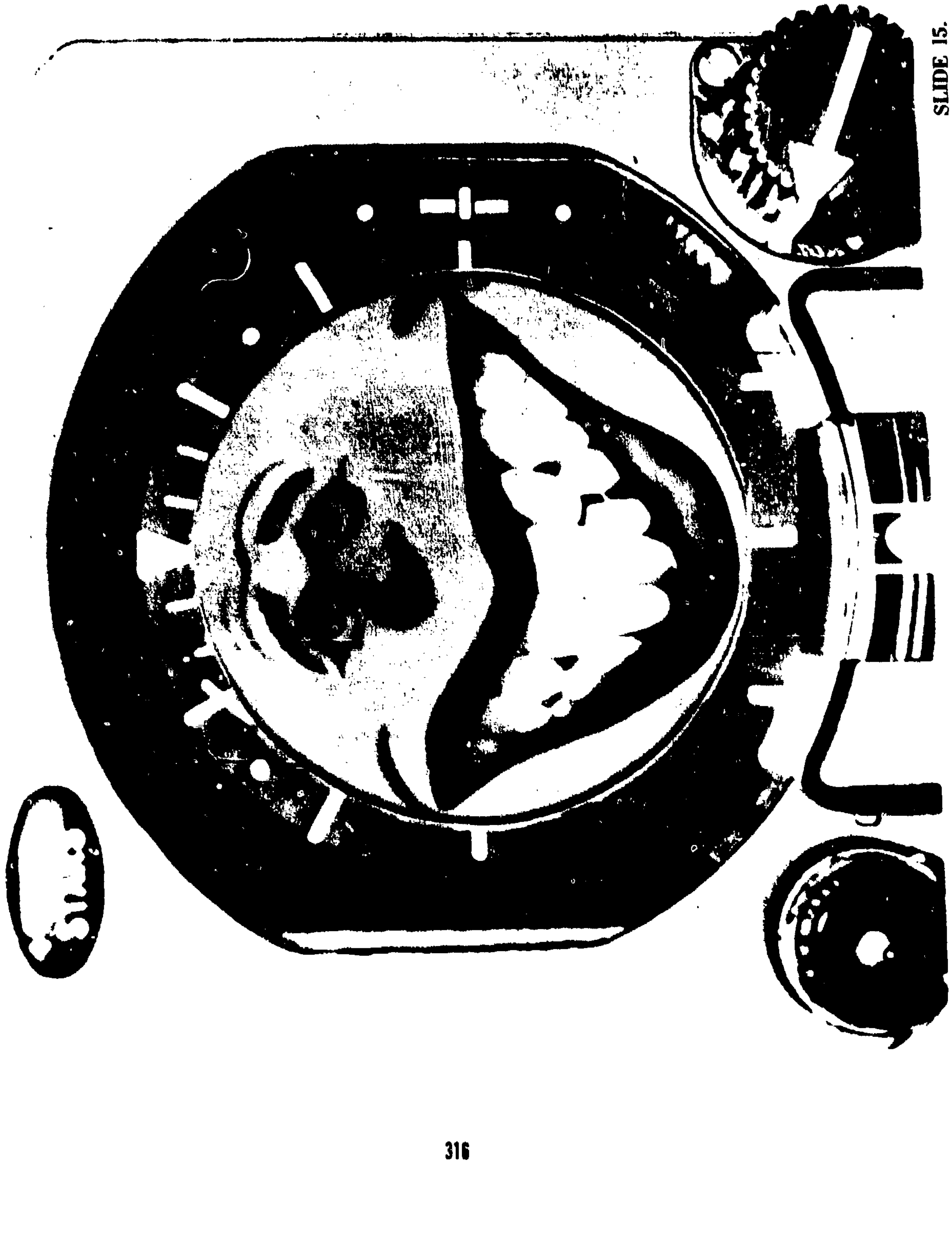
ADF
REV
FM
NAV SEL

SLIDE 14.



SLIDE 15.

MR. HATCHER: Thank you, John.

Next I would like to introduce Jim Klein of Collins Radio Company. Mr. Klein is the flight control engineer in the avionics section there and he is currently the systems engineer for the VTOL control display technology program conducted by Collins for the Flight Dynamics Laboratory of the Air Force. Jim:

JAMES A. KLEIN
COLLINS RADIO COMPANY

Thank you. I took my prepared speech yesterday and threw it away. Since yesterday, a lot of people have said a lot of good things. I don't want to repeat them, so I think I'll just summarize a few things. The presentations given here yesterday and today indicate that much can be done to improve VTOL IFR capabilities. It is now within the state of the art, using integrated circuits and new technologies, to provide an economical sophisticated flight control system for the light to medium class helicopters.

I would like to reiterate the need for a systems design approach. This was mentioned yesterday and I'd like to hit that again. We need the systems design approach to solving the helicopter IFR problem. Not just adding black boxes or pretty displays as they come along, but define what the problem is and approach it with the whole systems concept.

We cannot, admittedly, solve all of the world's problems at once. But given a good problem to work on, I am sure that any of the avionics people here today can go out and solve the problem, given a good definition of the problem. So I'd like to indicate five steps to solving the problem.

First of all, you have to know what the problem is and it's more than just "night IFR" or "night capability" or "IFR in all kinds of weather." We need to know a little bit more than that. We need to know: is it continental United States or is it out in the field with a man holding a beacon waiting for you to come down to him. We need to know a little bit more precisely what the problem is. If we have a good handle on the problem we can then charge off and come up with a solution.

Step number two is to do our background analysis. This is both quantitative and qualitative. In the quantitative area, we need a math model of the vehicle, simulate it -- take a look at what it can do, with the mission requirements in mind. The analysis will right away tell us if we need a SAS system, for instance, or in what axis we need the SAS system and if it needs to be a smart SAS or a dumb SAS. This can be seen just by taking a look at the analysis and the mission requirements, even before we fly the vehicle.

The third step comes after we have decided what we need to solve the mission. For instance, we may need a SAS in a particular axis or a boost here or there. We can then put it on a simulator and have the pilots evaluate it. We haven't built any hardware yet. We have some ideas that the "think type" people have come up with and these are not necessarily always good ideas. We need to put these ideas in front of the pilots and let them take a look at them. No hardware is built yet, but if the concepts are viable, we can go out and build them. If they're not, we back up into the analysis area and try to come up with something better. It's an intricate process.

Okay, so assume we have a good idea and the pilots seem to think it's worthwhile. Now we can go out and build it. Once we have got it built we put it in a flight test vehicle. I think this is an important step. We can't just go from simulation to a final product. We need to go from the simulation to a prototype; get it out in the actual vehicle and fly it. There are a lot of things different with flying a system than riding in the simulator. You have the shake in the butt and the pucker factor, and everything else that gets in there. Not only that, but a simulation admittedly is not 100 percent correct, so we have to go to the vehicle anyway. With that in mind, I can go back one step. Since we know we are going to flight test, we don't have to put all our money in the simulation. We can have a compromise on the simulation because we are going to flight test the system anyway. So we can do a tradeoff. Flight testing is very expensive, so we want to do some simulation but we don't want to go to the "nth" degree in simulation either.

Then after the system has been flight tested, and maybe gone back and been reworked through analysis and simulation again, we now come to what we think is a production system. I still don't think it is something we want to put on the shelf to sell yet. Now we want to go into a user evaluation of it. In other words, a PIFAX program, such as Chip Winter talked about yesterday.

Those are the five steps I am advocating for the good system design.

We at Collins have been in the avionics field for many years now, working in the area of flight controls. For example, the flight director installed on the Scout, one of the three mentioned by Captain Coleman yesterday, was a Collins system.

We have developed SAS systems and one was mentioned by Mr. Winter on the UH-1; it's more than just a SAS system, it's a smart SAS. It will hold heading or it will coordinate, depending upon what the pilot's wishes are. If he wants to coordinate, he attempts to coordinate and the system will take over and coordinate automatically for him. At low speeds where you don't want excessive bank angles if you get a little yaw rate, it goes out of turn coordination and into a heading hold situation.

We are active in the area of 3-cue displays. In the program that I'm currently working on that the Flight Dynamics Laboratory is directing, we are using a 3-cue flight director. I guess I'd like to throw in one comment at this point: it is that I feel strongly in vector control. In other words, we don't want to control just the airspeed or just the let-down rate in the terminal area, we want to control flight path angle. We want to take a look at what the vector is doing, not the components that make it up, but the whole vector. The cues and the displays are built with this in mind. Vector control – what do you really want to control? You don't want to necessarily control airspeed or let-down, you want to control flight path down to a spot. On this program we also want to maintain the pilot as an active element in the loop. We don't want to go all automatic and let him sit there and watch the stick wiggle back and forth, because if something fails, he will have to get back in there and reestablish his control again.

Collins in also in the area of NAV/COM, as everybody is well aware.

In summary, I'd like to say that we can't solve all the problems at once, but we feel using the systems approach to the solution, it is within the state of the art to solve any mission requirement if that mission is well defined.

Thank you.

MR. HATCHER: Thank you, Jim.

Last but not least today is Mr. Shacklock, of Teledyne Ryan Aeronautical Company. Mr. Shacklock, an aviator, has been with Teledyne Ryan since 1960 and has worked in radar simulators, target drone aircraft, and is presently responsible for development of a simplified, terrain following radar for helicopters. Floyd:

FLOYD B. SHACKLOCK
TELEDYNE RYAN AERONAUTICAL COMPANY

Thank you. First of all, I'd like to say that this conference has been very enlightening to me and very beneficial. It will help companies such as ours in applying our technology better to your requirements. I won't try to elaborate on what the problems are or what the specific solutions are, but I'll try to present to you, briefly, some of the sensors that we are working on that we think have application to your problem.

First slide, please.

First of all, terrain following radar. This is a company funded program. It's in the early development stage and hasn't been fully polished yet. Terrain following is a maneuver in a pitch plane only. We don't try to fly laterally around the obstacle, we are talking strictly about adjustment of your altitude as you fly a straight course line. What we think might be a little bit different about the sensor we are developing as compared to others that we read about is that we are trying to aim at a very minimum sensor. The smallest, lightest sensor we can come up with, to do that first step of capability.

Next slide, please (slide 2)

We are trying to improve the pilot's present capability to fly his aircraft. The difference in approach might be that we are not trying to jump into the middle of the IFR problem now and say we have all you need. We are trying to take what we have now and see if we can build a little capability on that. Now after what I heard yesterday about pilot workload, I think I put my foot in it with that first statement, but needless to say, in our sensor we are not attempting to make decisions on how the aircraft should be climbed, for instance. The output of our sensor is an indication that the vehicle needs to climb and we are leaving that to the pilot and his integrated displays and other systems. We are trying to keep the sensor as simple as it can be; it is a continual temptation to incorporate frills and features. We feel these should only be put in the sensor if it becomes truly necessary, more than just desirable. Finally, as a guide in the design of the system, we feel we will compromise terrain following performance before we will compromise safety. In other words, our sensor will always indicate a climb if it is not sure that it's safe to descend. Terrain following performance compromise, meaning that the vehicle is flying at an altitude higher than you might want to be.

The system works much in the same manner as many terrain following radar systems, with a forward-looking radar and a radar altimeter. The radar altimeter we do not incorporate in our Model 622, we assume there is one on board the vehicle from which we take an output. The pilot's display is shown there, even before this meeting we knew we were not going to supply our displays permanently. We have put them on here to show you the type of information that the sensor develops. It seems certain that the best way is to incorporate the displays in one of the integrated display systems, that we have heard about during this conference.

The logic that is used in terrain following is not unique to this system, but a quick review might be in order. The system indicates that the vehicle should be climbed; that it should increase its terrain clearance if either the radar altimeter or forward looking radar senses that it is appropriate to do so. The sensors operate independently through exclusive logic to indicate climb whenever one might be appropriate. A descent is not commanded or indicated until both sensors indicate that it is safe to do so. The displays that we have used in our flight tests have included the horizontal bar to indicate a climb or descent command. We don't have the integrated display problem resolved yet. The horizontal bar in an integrated display would probably indicate some other command, so we will be working with the display people to find the best indication on the display that the vehicle should climb or descend. A brief comment about the forward looking radar. It's more than just a beam sitting out there. First of all, it scans through a range of angles so that a climb can be initiated at a distance proportionate to the size of the obstacle which is upcoming. Secondly, the forward looking radar has to be stabilized in pitch for the changes in attitude of the aircraft. The scan pattern is always kept out on the horizon; and finally, the forward looking radar has provisions so it can be moved left or right in azimuth to correct or to take into account the drift angle of the vehicle. This correction for drift angle can be accomplished either manually or it could be accomplished automatically if a doppler velocity sensor or an inertia sensor were aboard the aircraft.

Next slide, please (slide 3)

This is a picture of some of our local company flight test activity. The terrain following pod is the small pod on the starboard side of the aircraft. The indicator we showed you before, the horizontal bar was the climb-descent indication. The vertical bar we use to indicate the position in left, right, or drift angle position of the antenna. The bug on the left side of the indicator was the radar altitude. The essentials are the climb guide command and the present radar altitude. The control inputs are directly below it. The pilot first of all can select the altitude at which he wants to fly, adjustable from 50 feet on up; second input is the drift angle selection. He has to determine the direction of the wind from some other sensor if he is drifting left and right and put that into the sensor so it's looking in the right direction and, finally, the "on-off" switch. Those are the only inputs to the system.

The terrain following radar itself – This is the pod you saw on the aircraft. Six and one-half inches across, some 30 inches long; present weight, 27 pounds. We are doing our best to keep the weight down. We feel that in any kind of a production situation, the weight of the pod would be about 20 pounds.

One thing the forward looking radar will not do is to see power lines, which are certainly a problem. We have incorporated into this pod, which will be going into evaluation here shortly at ASTA, a separate sensor that is designed to sense the proximity of power lines by sensing of the electrostatic field. We have flown it on our flight test vehicle and have had good sensitivity. The sensor we will be flying here will not have directional sensing. We have flown one version that has directional sensing, but have not had time to incorporate the directional feature in this particular pod. The field of power lines first of all depends upon the fact that the power line is indeed carrying a voltage. Further, it depends upon your altitude with respect to the power line. If you're at or below the power line altitude, the field is much stronger and you will sense the line at a much greater range than if you're above the power line. The sensor certainly won't see power lines that are not carrying a high voltage. It's not a cure-all to all the wire problems, but the weight of the sensor is certainly less than a pound and it will see a lot of the wires. We find it a useful indication of power lines in the vicinity where we are flying. The display is simply a light in our system that comes on, telling you that there is a power line in the vicinity, and you had better look out; or if you can't see out, you had better climb up above the anticipated power line altitude.

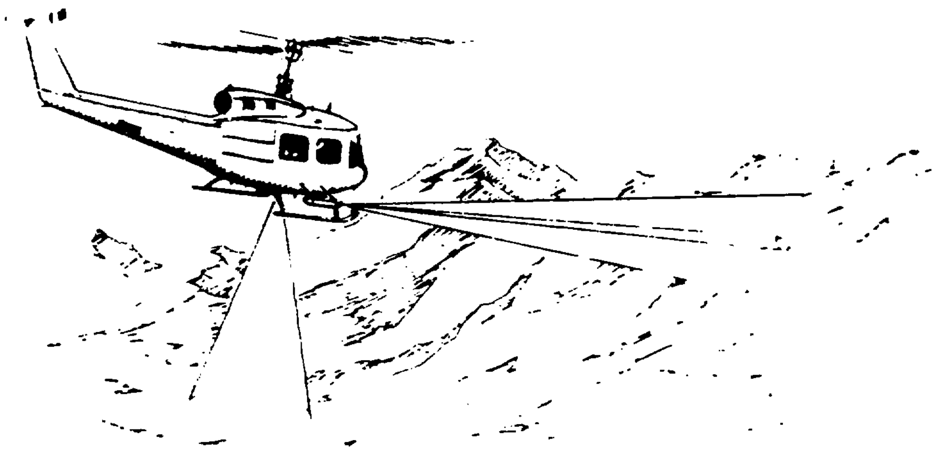
I will briefly mention one other sensor that Teledyne Ryan has developed and is pertinent, we feel, to the helicopter IFR problem. That's the doppler velocity sensor currently undergoing evaluation at ECOM. I'll show you a couple of pictures of the sensor itself. This is a velocity sensor, 8 by 16 by 4 inches, weighing some 18 pounds in this development stage, down to 15 pounds for the sensor is a production situation.

Next slide, please (slide 4)

If we can go to the next slide quickly, on the unofficial result of the evaluation at ECOM, it is our interpretation of the official evaluation. First, on a moving earth simulator we locked on velocity at altitudes at and above 4 feet when we had a tenth of a knot of velocity. This is an important thing in doppler velocity sensors. When velocity is truly zero, you have nothing to measure and you can't acquire it, but we feel that with this kind of sensitivity, we can certainly achieve good navigation accuracy. The blind hover test measures the ability of a pilot to stay over a spot purely on the information supplied him by the doppler velocity sensor. To stay within the 25-foot circle for 10 minutes indicates the good response to near-zero velocity. And finally, in nap of the earth flying down a particular stream bed over slick water, we still maintain the half percent distance traveled error.

TELEDYNE RYAN AERONAUTICAL

TERRAIN FOLLOWING RADAR SENSOR FOR LIGHT AIRCRAFT AND HELICOPTERS



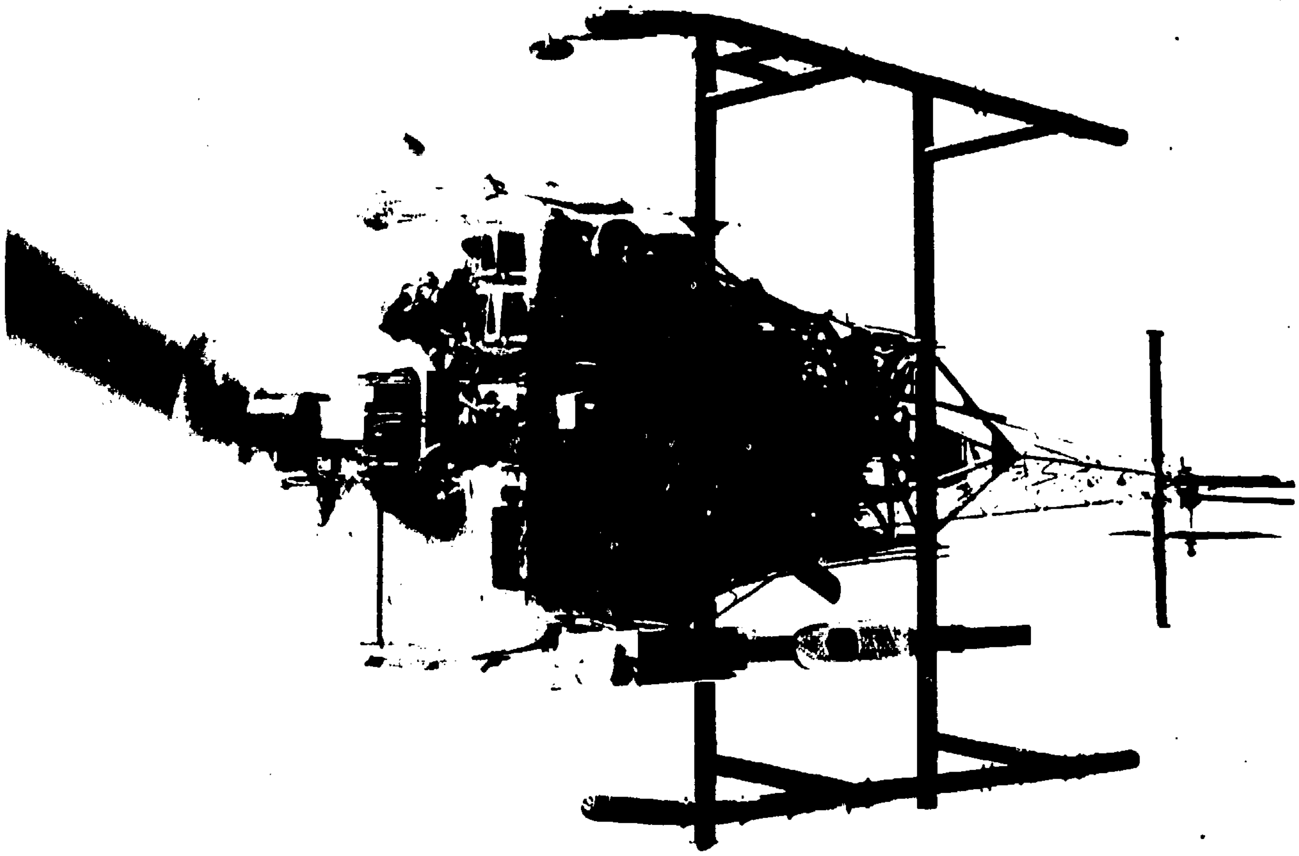
SLIDE 1.

OBJECTIVES

TO IMPROVE THE PILOT'S ABILITY TO
FLY HIS AIRCRAFT AT LOW ALTITUDE
UNDER CONDITIONS OF REDUCED VISIBILITY

SLIDE 2.

SLIDE 3.



ECOM FLIGHT-EVALUATION RESULTS (UNOFFICIAL)

MOVING EARTH SIMULATOR .... LOCK AND TRACK AT 0.1 KNOT AND 4 FEET ALTITUDE

NAVIGATION .... 0.5% ERROR

BLIND HOVER .... DRIFTED LESS THAN 25 FEET IN 10 MINUTES

NAP-OF-THE-EARTH .... NAV. ACCURACY OF 0.5% FOR 1 HOUR FLIGHT ALONG DIFFICULT COURSE

SLIDE 4.

MR. HATCHER: Thank you, Floyd.

Let me say thanks to all the speakers here and let me just summarize in one sentence that it behooves us in the government to sit back and determine our requirements for platform stability, determine augmentation required to achieve that, and then look at the navigation, energy management, and integrated display capability that industry has recommended. If we judiciously apply it to our mission requirements, we can, indeed, end up with reduced pilot workload, improved flight path accuracy with improved safety for expanded mission capability.

Thank you.

SESSION III

PANEL 2

HARDWARE CAPABILITIES AND FUTURE NEEDS
AIRFRAME MANUFACTURERS

MODERATOR

COLONEL LESLIE H. GILBERT
US ARMY MATERIEL COMMAND

PANELISTS

MR. PAUL THERIAULT, LOCKHEED-CALIFORNIA COMPANY

MR. RICHARD STUTZ, SIKORSKY AIRCRAFT

MR. RODNEY TAYLOR, HUGHES HELICOPTERS

MR. THOMAS SANDERS, BOEING-VERTOL

MR. JOHN C. KIDWELL, BELL HELICOPTER COMPANY

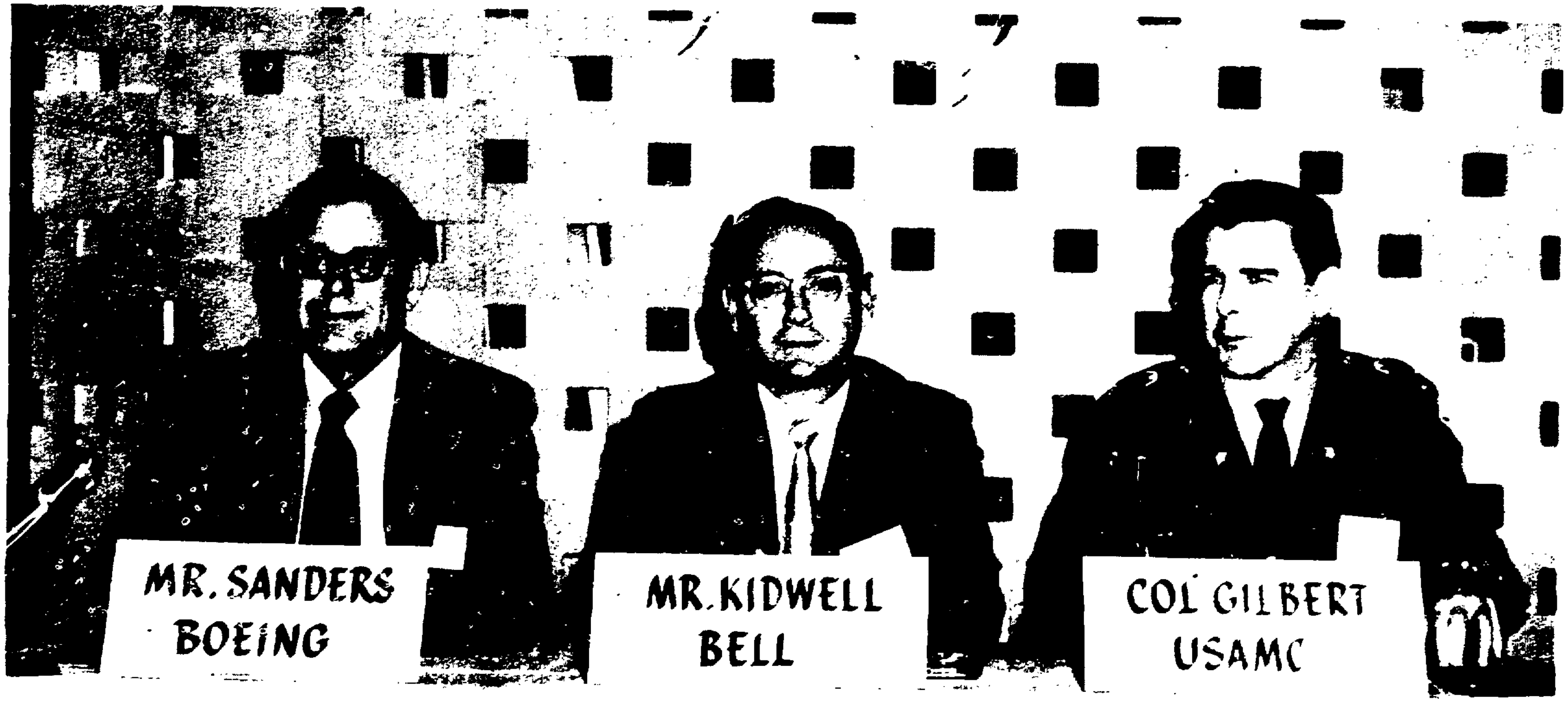


PHOTO 1. SESSION III. PANEL 1.

PHOTO 2. SESSION III. PANEL 2.

INTRODUCTION OF PANEL ON HARDWARE CAPABILITIES AND FUTURE NEEDS AIRFRAME MANUFACTURERS

COLONEL LESLIE H. GILBERT
DIRECTORATE OF RESEARCH, DEVELOPMENT AND ENGINEERING AIR SYSTEMS DIVISION
US ARMY MATERIEL COMMAND

This is what you have all been waiting for – the final session of this very motivating conference on helicopter instrument flying. During the past day and a half now we have heard ASTA talk about the testing of some current helicopters with some standard instruments as well as some advanced instrument flying aids. We have heard from other government agencies outside the Army and the types of things they are trying to do in the area of helicopter instrument flying and associated developments. We heard from Bill Crouch's panel on the future needs of the Army in describing general areas we are trying to get to in the way of capabilities and what not, and in the last panel we heard about how the avionics folks are contributing to this very important area. So now we are down to this panel and it's my privilege to chair this panel where we are going to hear from some distinguished members of the principle helicopter manufacturers and/or developers in the United States. So without any further ado, I'd like to introduce our first speaker, Paul Theriault, of Lockheed. Paul has been with Lockheed almost forever – 31 or 32 years, after having graduated from the University of Michigan. He has had a variety of positions in that company. The last half of his 30 years has been in rotary wing, primarily. He has been the Chief of the Rotary Wing Design Section. He has been in engineering, project manager of the rotary wing program, and he most recently has been advanced to Director of Sales for rotary wing aircraft. So, Paul, the floor is yours.

PAUL THERIAULT
LOCKHEED-CALIFORNIA COMPANY

Our studies at Lockheed have been focused in the areas in the environment described by LTC Weatherbie, as in a combat situation where flight in and out of IFR probably would be frequent, nap of the earth operation, or flying in black of night under low level light conditions under combat situations with the crew under combat stress. In looking at the requirements for such an operation, ideally we would like to have a passive system for presenting to the pilot as complete a display of the surrounding territory as possible. We have leaned in this direction simply because of the idea that he would be in and out of IFR and would have to make the transition from IFR to VFR rapidly. We thought ideally we would like to present to him a picture of the surrounding terrain such that the transition could be affected very easily. We wanted a passive system so that there would not be any signature for the enemy to detect and as I say, we would like to make it a one to one magnification or view, such that the transition is effected from IFR to VFR. Initially our approach to satisfy some of these requirements was to use an automatic terrain following system, such as Mr. Shoenberger has described, employing a five-axis autopilot with the manual terrain avoidance feature incorporated. This system was designed and planned for the AH-56. It was subsequently eliminated from the program from a cost saving standpoint and subsequent to that, the developments in the IR sensors, first applied in our particular case as a gunner night vision system, appeared to offer a potential for pilot night vision capability and low level nap of the earth capability. This we have more recently been studying and I think the first slide lists some of the requirements as we see them for an infrared system as applied for IFR flight.

First slide (slide 1)

We, as I say, have looked at the FLIR system from the standpoint of its excellent atmospheric penetration and its performance in any light level. We feel, however, if the sensors are going to be fixed in their view, they must approach a 90 degree field of view or if they're going to be articulated, the instantaneous view ought to be in the order of about 30 degrees. Furthermore, since it is not 3-dimensional, it must have symbology to give the pilot the additional cues necessary for the nap of the earth flight under these conditions. The magnification, again as I mentioned, should be one to one or close to it, so that the transition from VFR to IFR and vice versa can be effected easily, and as everybody has pointed out in prior conversations, a radar altimeter is essential to this part of the operation. One of the real crux issues actually in this situation is the display and the next slide will illustrate some of the potential display systems.

Next slide, please (slide 2)

We have had discussions of panel-mounted CRT's. This certainly is an applicable display in this kind of a situation using an IR sensor. A heads-up display has the advantage of getting the pilot's head up out of the cockpit with the ability to look forward simultaneously with the display of the sensor. A panoramic display such as the henilas display could be used and finally perhaps a helmet mounted display bringing the image in close proximity to the pilot's eyes so that the one to one magnification and perspective can be maintained. We feel the display should have a standard TV format. This ensures good resolution and provides a degree of flexibility and as I mentioned, we feel at the present time, symbology must be displayed along with the scene to give the pilot, as a minimum, symbols of radar altitude, the horizon, pitch attitude, and ground speed for complete capability.

What I'd like to do now is briefly show some pictures of the four types of displays.

Next slide, please (slide 3)

The first one shows a CRT mounted on the panel. This, of course, crowds the already crowded instrument panel. We feel to give adequate perspective again to the pilot, it has to be at least 20 inches in size or larger. It has the disadvantage from a night standpoint of lighting up the cockpit. It requires the head down in the cockpit, the eyes in the cockpit and again, confuses the issues of transferring from inside the cockpit to outside. It's one advantage, it's a standard display, employed today, and could be displayed in this particular situation at a relatively low cost.

Next slide, please (slide 4)

This slide shows a heads-up display. This using a curved glass – a see-through display. This, again, must provide a field of view of 30 degrees if we are going to give the proper perspective to the pilot. It is a relatively costly display with the curved optics to provide the field of view and again, it also lights up the cockpit. It does have the advantage, of course, of being mounted above the instrument panel so it is eliminated from the crowded instrument panel. This has been looked at from the standpoint of possibly mounting it on a rack so it can be pulled out closer to the pilot, again, to give him proper perspective of the scene that the sensor is viewing.

Next slide, please (slide 5)

This slide shows a panoramic display, a henilas type of display. This gives a 180 degree field of view essentially and provides the pilot with the kind of view that he would normally be flying under a VFR condition. The sensor is mounted above the pilot. It rotates, surveys the situation and projects the image on this display. Unfortunately, of course, this one blocks out the entire instrument panel. He has to fly entirely by the display and this would prevent, of course, a rapid transition IFR-VFR.

This slide shows a photograph of a typical situation on such a display, showing the kind of a scene that would be displayed to the pilot with the 180 degree field of view. He does not require symbology. He gets enough 3-dimensional effect and coverage that it is felt that the symbology could be dispensed with in this particular situation.

Next slide, please (slide 6)

Next is a helmet mounted display. This was an adaptation we made and tested in the AH-56, utilizing the gunner's FLIR system – infrared system for display – as a sensor displaying on the helmet mounted sight in front of the pilot's eye. It was mounted on the right-hand side of the helmet and gave him a monocular view of the display as sensed by the infrared sensor mounted in the gunner station. This was flown without any symbology and it pointed out the need in this particular instance, since it was a monocular view, although of one magnification, it did point out the need under those circumstances for symbology to be presented to provide the pilot with the additional cues he needed for adequate flight capability near the ground. However, this has the advantage of directing the sensor by motion of the head and helmet so that the pilot can see the scene that he is looking at directly by slaving the sensor with the helmet position. He then sees the picture at any direction that he may be looking.

Next slide, please (slide 7)

Another concept of a helmet mounted display is shown on this slide in which the display conceivably could be projected on to the visor of the helmet. This again gives a better perspective to the pilot. If he wants to convert to strictly VFR, he simply flips the hood up, getting it out of the way, but it also is a "see through" view so he can see the IR sensors display on the helmet visor, as well as the "see through" capability to see the view by eyeball. This again has the advantage of being able to direct the sensor by the means of the helmet position and gives the pilot the view that he happens to be facing.

Next slide, please (slide 8)

This slide shows the type of symbology that we would plan to incorporate in a helmet mounted display. This shows the artificial horizon, the RMI steering bar, and the altitude pips to give the pilot the kind of additional information over and above the scene that might be projected from the IR sensor.

Next slide, please (slide 9)

This next slide speaks to the goggles that are light augmentation systems, not IR, but these offer the advantage of simplicity and low cost. They can be slipped up out of the way or slipped down into position. They can be bifocal so they can focus on infinity or in the cockpit sumultaneously. They, of course, do depend on some light level for performance but offer a fairly simple and low cost system for night flying providing there is at least a half moon light or star light available.

Next slide, please (slide 10)

The next slide speaks of the advantages and disadvantages of the goggles. Again, it's a low cost system. There is no need for symbology, he can utilize the bifocal system for cockpit reference. The drawbacks, of course, are the fact that it does require external light level for satisfactory operation.

Next slide, please (slide 11)

The last slide speaks to the areas of development that we think must take place to further make the IR systems a practical approach. The first one is quite obvious under our design for cost philosophy these days; that the cost of the systems must be reduced. The cost of the symbology generators is still quite high and those costs should be brought down before the system can be considered universally applied. Newer and smaller display improvements in this area, as I mentioned, less expensive means to display the analog symbols. We still do not in this system have a good way to detect wires and cables. This still is a problem yet to be solved in this type of display. We'd like to be able to eliminate the symbology requirements by giving the pilot some way of achieving depth perception. If we could give him a view with depth perception included, we could get rid then of the symbology and again as an adjunct to the night vision operation, a good navigation system, telling the pilot where he is at all times and the simple low cost would enhance the night flying capability, the night time operation. Thank you.

SENSORS FOR IFR FLIGHT

- FORWARD LOOKING INFRA RED "FLIR" BECAUSE OF EXCELLENT ATMOSPHERE PENETRATION AND PERFORMANCE IN ANY LIGHT LEVEL.
- SENSORS MUST HAVE IN EXCESS OF 90° IN VIEW-FIELD WHEN FIXED. ARTICULATED SENSOR MUST HAVE VIEW-FIELD IN EXCESS OF 30° PLUS SYMBOLOGY.
- MAGNIFICATION SHOULD BE 1 : 1 OR NEAR TO IT.
- RADAR ALTIMETER WITH BAROMETRIC BACKUP ESSENTIAL.

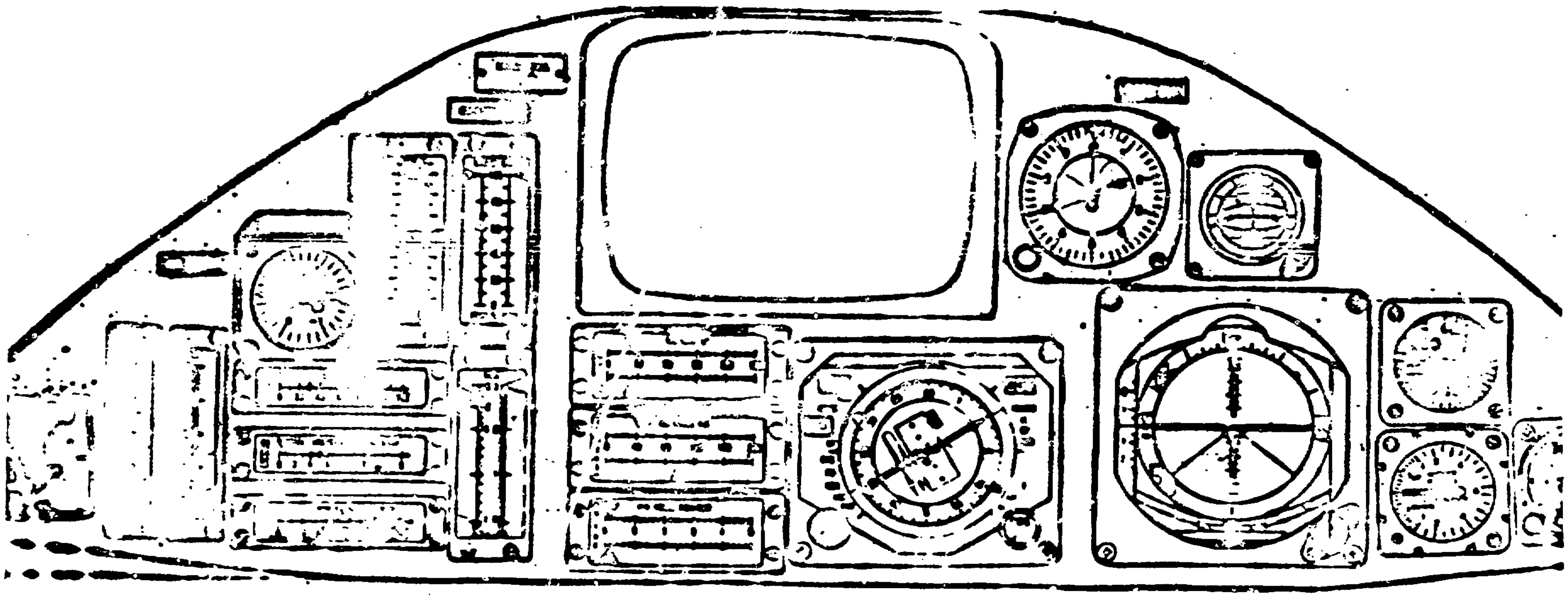
SLIDE 1.

DISPLAY REQUIREMENTS

- FOUR BASIC WAYS TO DISPLAY IMAGE
  - PANEL MOUNTED CRT.
  - HEADS UP DISPLAY (HUD)
  - PANORAMIC DISPLAY
  - HELMET MOUNTED DISPLAY
- SHOULD HAVE STANDARD T.V. FORMAT. INSURES GOOD RESOLUTION. FLEXIBILITY.
- MUST HAVE SYMBOLOGY GENERATOR WITH FOLLOWING MINIMUM SYMBOLS:
  - RADAR ALTITUDE
  - HORIZON
  - PITCH
  - GROUND SPEED (ESPECIALLY FOR LOW VALUES - LANDING)

SLIDE 2.

PANEL DISPLAY



DRAWBACKS

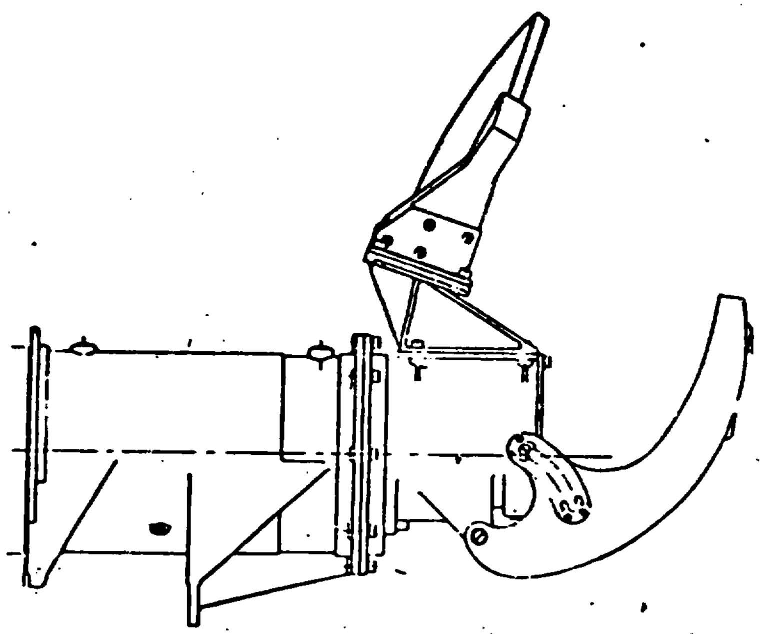
- OCCUPIES VITAL PANEL SPACE
- [illegible] LARGE 20" +
- GIMBAL MOVEMENT MAY DISORIENT PILOT
- COCKPIT LIGHTED UP - INCREASES VULNERABILITY
- PILOT MUST LOOK DOWN TO SEE IMAGE.

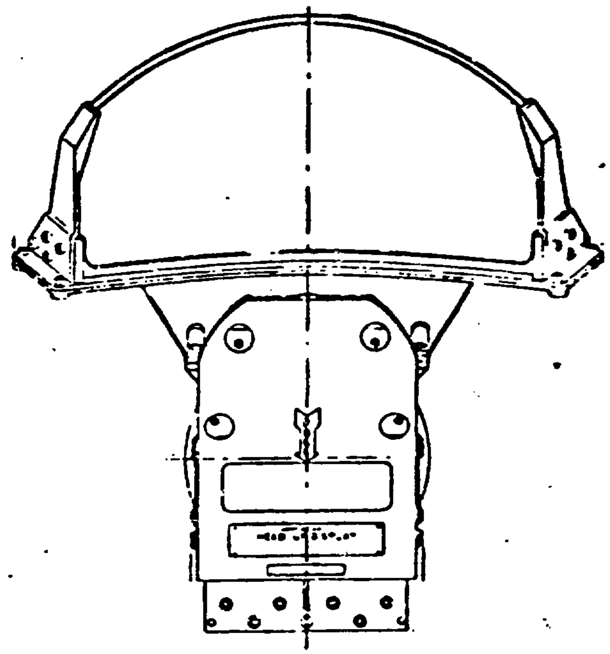
ADVANTAGE

- STANDARD DISPLAY - LOW COST

SLIDE 3.

HEAD UP DISPLAY





DISADVANTAGES:

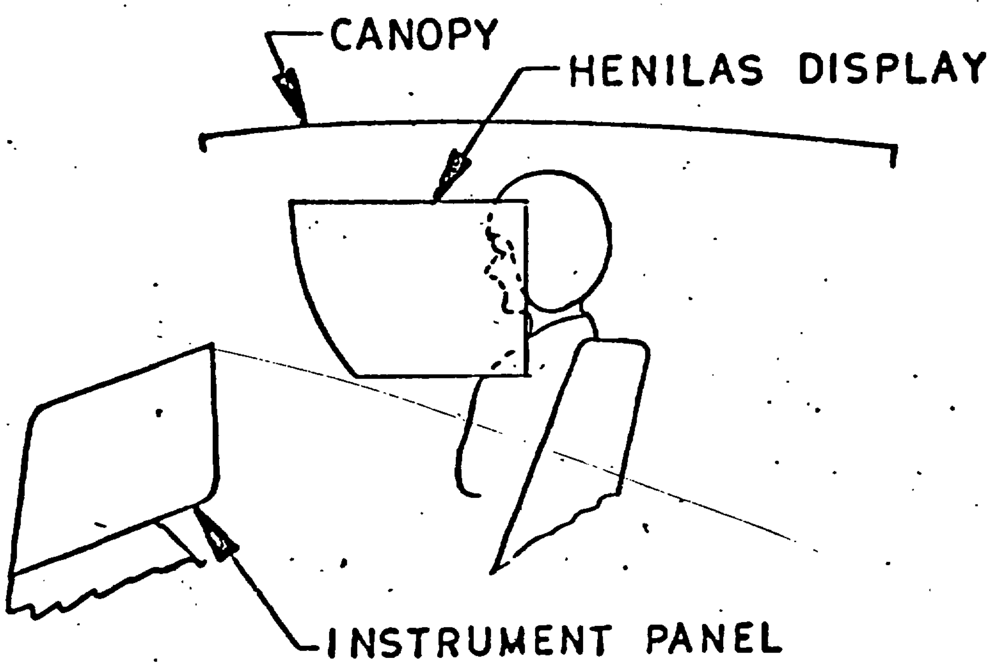
- MUST BE LARGE TO GIVE 30° + FOV.
- LARGE CURVED OPTICS COSTLY
- LIGHTS UP THE COCKPIT, MAKES AIRCRAFT VULNERABLE

ADVANTAGES:

- DOES NOT DISTURB PANEL - CAN BE AN ADD-ON
- LETS PILOT LOOK STRAIGHT AHEAD AND SENSE HORIZON
- CAN BE USED FOR FIRE CONTROL

SLIDE 4.

PANORAMIC DISPLAY



DRAWBACKS

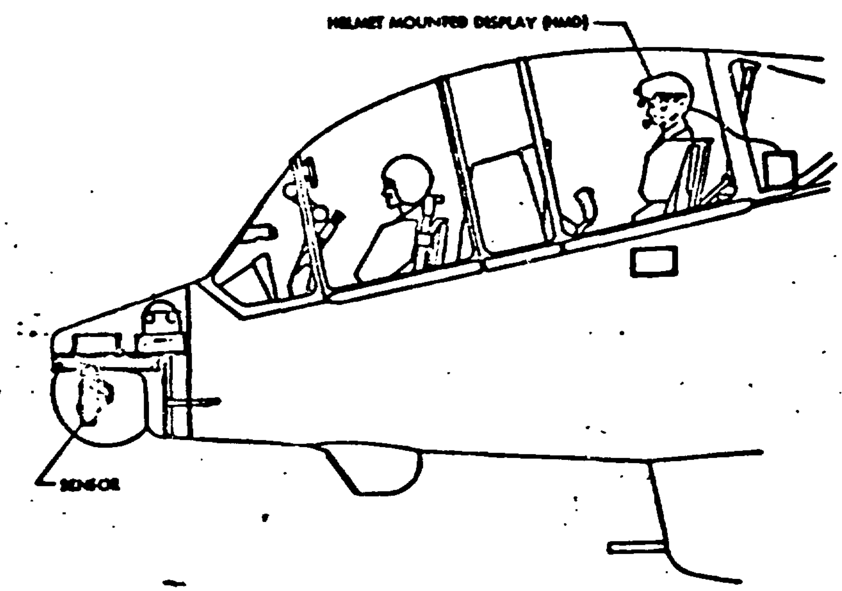
- OPAQUE SCREEN BLOCKS COCKPIT VIEW AND OUTSIDE VIEW.
- LARGE SCREEN DIFFICULT TO REMOVE IN EMERGENCY
- SENSOR MUST BE ABOVE PILOT CAUSING CRASHWORTHINESS PROBLEMS.
- DOWNLOOK LIMITED.
- LIGHTS UP COCKPIT - INCREASED VULNERABILITY.

ADVANTAGES

- VERY LARGE VIEW FIELD
- NO SYMBOLOGY REQUIRED
- VERY HIGH INFORMATION RATE.

SLIDE 5.

HELMET MOUNTED DISPLAY



THE CHEYENNE EXPERIMENT

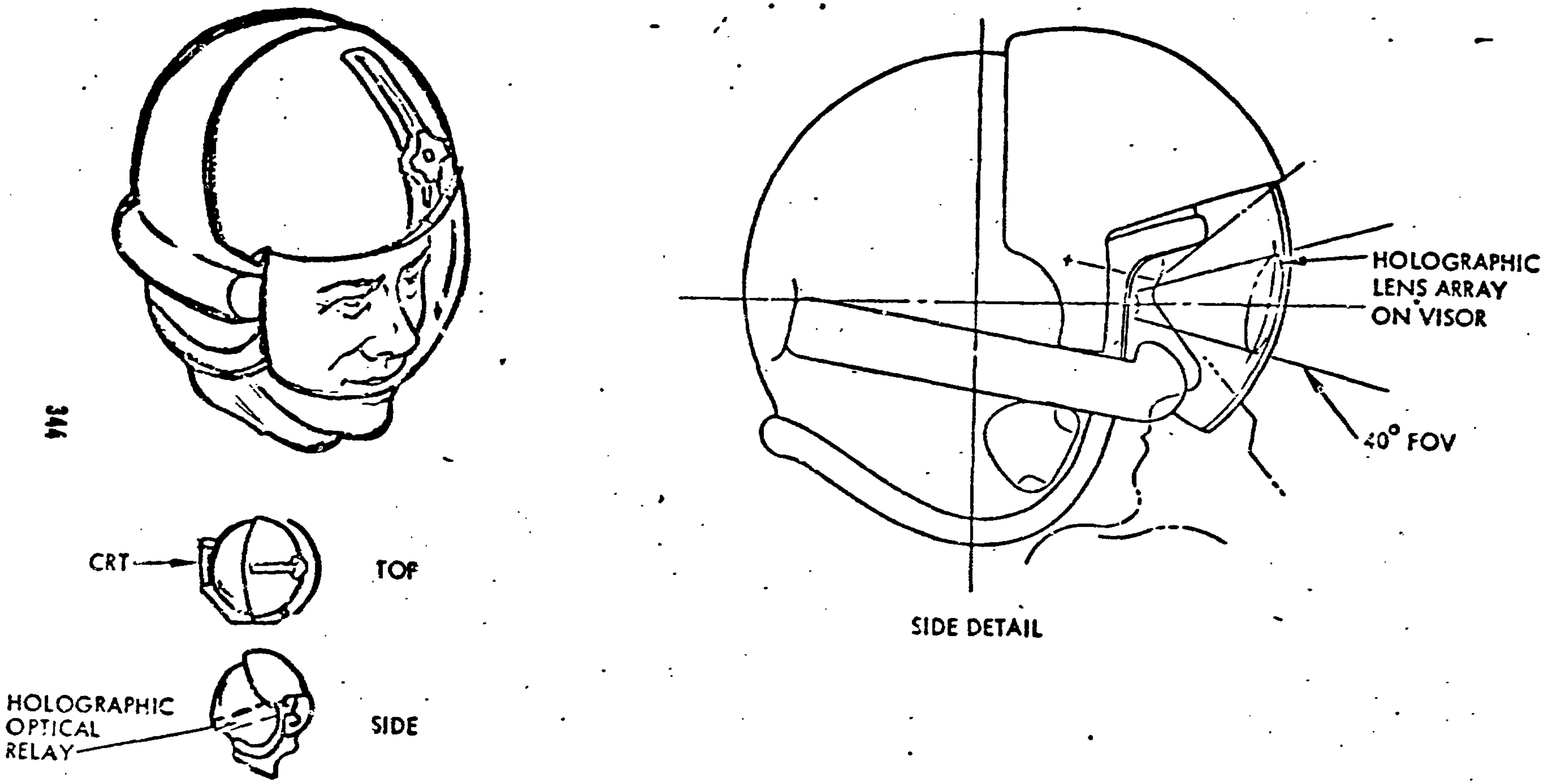
ADVANTAGES

- SCENE RELATED TO LOOK DIRECTION
- GIMBAL ARTICULATED BY HEAD
- VERY SMALL DISPLAY
- CAN DIRECT WEAPONS
- CAN USE VISOR
- SIDE LOOKING EASY
- CAN SEE INSTRUMENTS BY SYMBOLOGY

DRAWBACKS

- SYMBOLOGY ESSENTIAL
- APPRECIABLE PILOT TRAINING REQUIRED
- HOLOGRAPHIC DISPLAY NEEDS MORE DEVELOPMENT
- WEIGHT ON HELMET NOT DESIRABLE

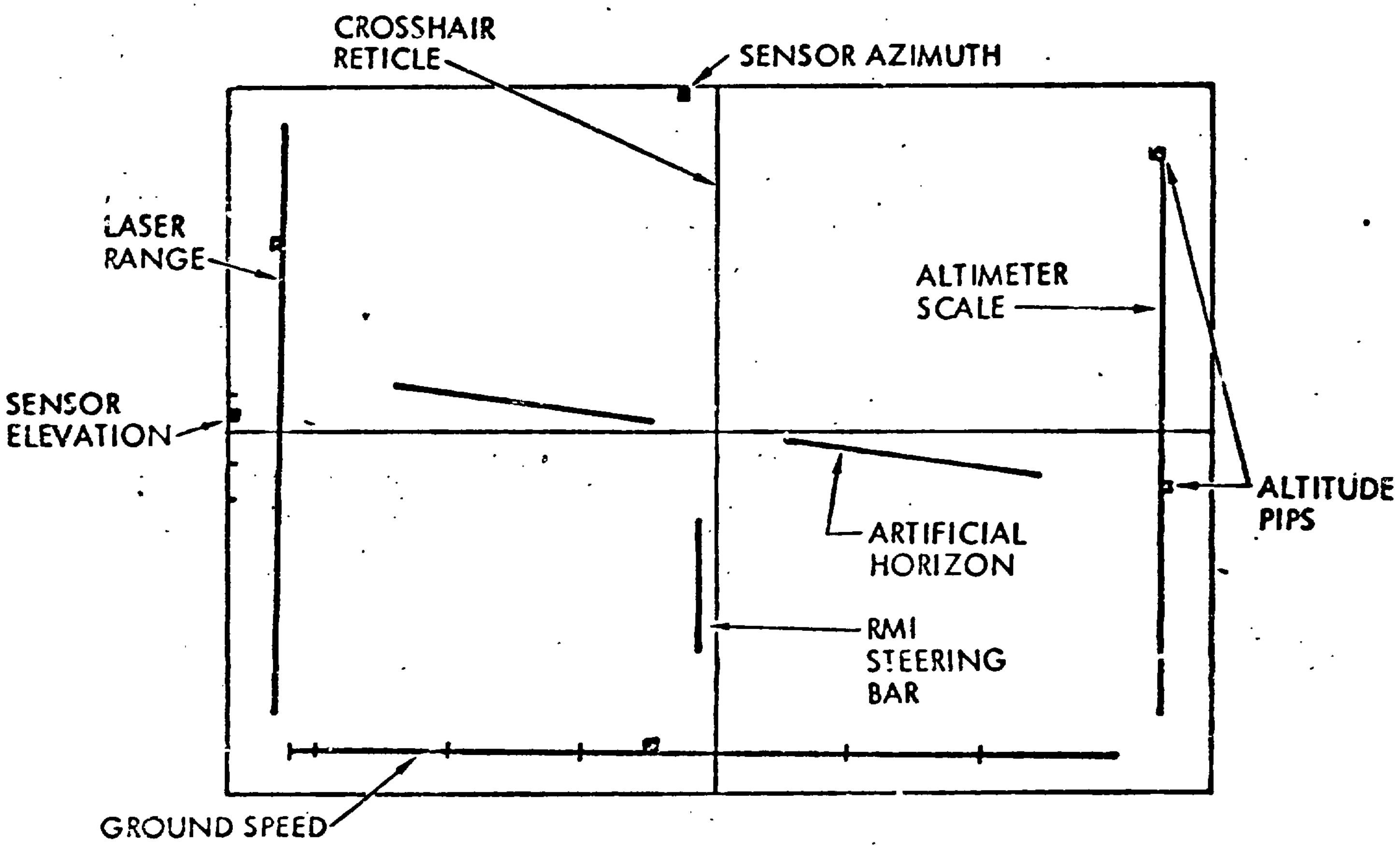
SLIDE 6.



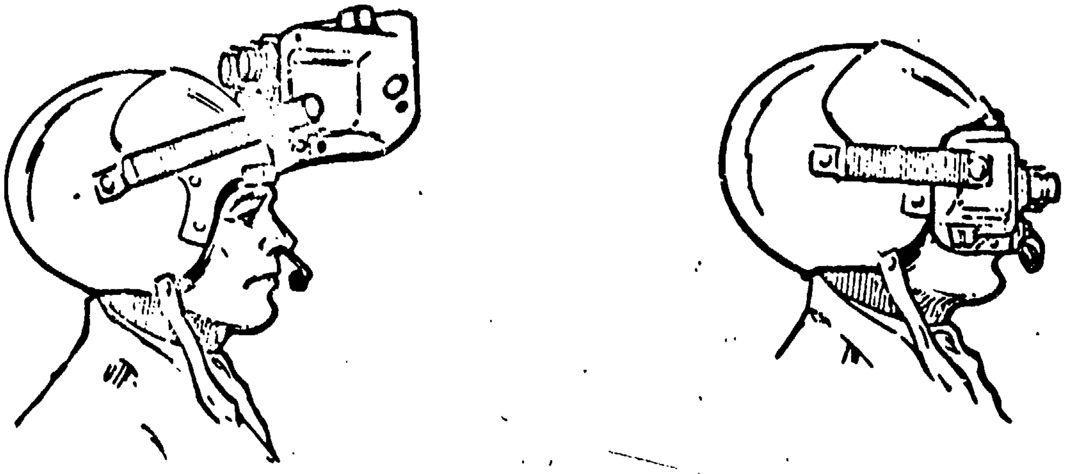
HOLOGRAPHIC HMD DETAIL

SLIDE 7.

DISPLAY SYMBOLOGY



SLIDE 8.



GOGGLE MOUNTING

WEIGHT	30 oz
MAGNIFICATION	1 X
FIELD OF VIEW	40°
DIAMETER	18 mm
RESPONSE	8-28
PHOSPHOR	P-20
FOCUS	BIFOCAL (∞ & 30in.)

GOGGLE PARAMETERS

SLIDE 9.

GOGGLE COMMENTS

ADVANTAGES

- SELF CONTAINED, BATTERY OPERATED.
- NO NEED FOR SYMBOLOGY, COCKPIT PROVIDES REFERENCE.
- LOW COST

DRAWBACKS

- WEIGHT ON HEAD
- COCKPIT INSTRUMENT VISIBILITY DIFFICULT
- POOR PERFORMANCE BELOW HALF MOON.
- SUSCEPTIBLE TO OVERLOAD BY LIGHT FLASHES.

SLIDE 10.

PROBLEM AREAS THAT

NEED FURTHER DEVELOPMENT

- AVIONICS COST MUST COME DOWN (STANDARDIZATION).
- NEW, SMALLER DISPLAYS REQUIRED (CHARGE COUPLED DEVICES).
- LESS EXPENSIVE MEANS TO DISPLAY ALPHANUMERIC AND ANALOG SYMBOLS.
- NEED MEANS TO DETECT WIRES AND CABLES FOR N.O.E. FLIGHT (LASERS, RADAR....).
- NON-SCANNING, UNCOOLED INFRA RED DEVICES (8 - 14 μ)
- DEVELOP DEVICES TO GIVE PILOT DEPTH PERCEPTION
- LESS COSTLY STABLE PLATFORMS FOR BACK-UP NAV.

SLIDE 11.

COL GILBERT: Very fine. Thank you very much. Paul is not being a coward by ducking out. He does have to get back to Los Angeles. When we get to the question and answer period, we do have a Lockheed representative here that will take care of any questions in that area. So thanks again, Paul.

Our next speaker will be Dick Stutz from Sikorsky. He has been with Sikorsky now for over 20 years and had a wide range of assignments at Sikorsky in the areas of design, research, testing and is currently the Chief of Flight Operations at Sikorsky. He got his advanced education at the University of Kansas. Dick.

RICHARD STUTZ
SIKORSKY AIRCRAFT

I think that Sikorsky's programs with the government have been covered very ably by Don Beck, Joe Watts, Paul Balfe, and others.

Most of you know that the Coast Guard, who are not represented here, fly our HH3's in search and rescue with hover coupler, Collins steering, and radar, equipment you saw in the KLM operation last night. At the present time also, I don't think Don Beck mentioned that we are currently evaluating, with the Navy, the SCNS self-contained navigation system at Sikorsky and following that on the same aircraft, we will be doing a manual terrain avoidance radar program with the Navy.

What I'd like to concentrate on here for a few minutes are two objectives that affect the Army's CONUS operations that are very important to us in the commercial area. The first is to meet scheduled transport airplanes with connecting helicopter service. At the same time we want to be able to conduct city center-to-city center operations in the same environment. This objective is, of course, a full IFR requirement. The second objective that we feel is very important is greatly increasing limited IFR capability in many existing helicopter operations. These two really go hand in hand as I will describe in a few moments. At the present time, the helicopters that we have in commercial service have Category I capability in instrumentation as far as visibility is concerned. We feel that this same instrumentation would be suitable for meeting Category II airplanes, if we enhance the landing areas with sufficient lighting. We have operated with this kind of capability with Los Angeles Airways since 1963, until recently. You saw the KLM operation last night. BAH Helicopters operates the S-61 with this capability as do the Norwegians with Nor Copters so we have some good experience.

We are not doing so well so far on icing. We only have one approval for icing so far – limited icing – with BAH Helicopters. The CAA has approved the BAH operation going into Aberdeen, Scotland, for limited icing and to provide this capability, they have ice deflectors for the engines, an ice rate indicator probe which is mounted on the aircraft, and a very carefully monitored programmed torque reduction which they use to control the amount of power they can use as the ice builds up. All of this is for getting up to 2000 feet so they can get on the conventional airplane ILS approach!

There are many things that we need to meet airplanes in Category III. One objective is to operate from a roof top with zero visibility out to meet the transport airplane which may have a thousand feet of visibility. This is a tough assignment. There are a number of things that we are doing about this. One is our S-65-200 commercial compound helicopter studies in which we are planning the capability of hovering with one engine inoperative. We also need terminal aids with approach angles greater than 3 degrees. We need icing protection and I was very pleased to learn the Army is developing a safe icing test facility for flight test that I think is a good addition to the required test capability. We also need reserved airspace so as not to compete with airplanes to make this operation attractive.

On the subject of reserved airspace, most of you familiar with our Los Angeles Airways operations know that we went out and joined the airplane ILS in IFR weather and slowed down the whole operation for everybody. New York Airways does not go IFR because there are no IFR aids at Wall Street. The only way we can expect to get reserved airspace attention and the terminal aids that we need for this kind of operation is to get enough people using IFR that it becomes a real consideration – a way of life. Joe Mashman pointed out that there are about 2500 helicopters in operation in continental U.S., 95 percent of which are utility helicopter operators, not commercial transport operators. These people need limited IFR capability to dispatch their helicopters through some clouds and out the other side VFR to get from one job to another. If they can get this capability with the existing equipment they have, we will get hundreds more operators and aircraft using some IFR and wanting to use terminals. This will be a real demand that the FAA can take seriously in terms of giving us the airspace and the kinds of terminal aids for up to full IFR operation.

In this limited IFR capability, we know that the Army has had a lot of experience. Their H34's have flown for years in Germany without AFCS in limited IFR. They have also flown the Hueys that way. If data from these operations could be made available, I think we would have a base for establishing limited IFR including required aircraft characteristics. This limited IFR must be regulated. I know the FAA will be concerned about what are allowable conditions to dispatch in such as ceiling and visibility, but I think that is the best way that we can get more capability and it is along the line that you were talking about, General Maddox, getting more capability out of the existing 2500 helicopters we have in commercial operations now. Is the Army's experience with the H34 and Huey a valid basis for FAA approval of limited IFR? We can exploit this. The FAA has already requested the information from the Aviation Safety Board at Fort Rucker.

Some of Sikorsky's IFR activities in our own IR&D program include coupling the 3-cue Sperry system into our CH-53 control system. We have already developed a LSS system for stabilizing external loads for heavy lift aircraft – slung loads. We would like to see the Army establish IFR requirements for 1- and 2-point suspended loads. We think this LSS system would be an attractive stabilizing system for those loads. We are also currently in a program with the FAA to certificate our S-58T for IFR operations.

Yesterday we heard about pilot workload in IFR operations and the importance of instrument reliability. Reduced vibration is one area in which the airframe manufacturers can work to improve IFR capability of helicopters. We at Sikorsky with our bifilar and other absorbers have substantially reduced the vibration levels throughout the flight envelope. As a result, pilot fatigue is less in instrument flight conditions and the instruments themselves are in an environment that their reliability is quite satisfactory.

I have some suggestions for further Army research in IFR, some of which have already been discussed here:

That the Army is developing a safe system for icing tests is of great importance. We will look forward to the opportunity of using that kind of technology. We would like to see more work done in the area of steep approach flying quality requirements – more than 3 degrees approach angle. We are very much interested in the development of the portable ILS system which the Army has supported. Again I want to emphasize that if the Army can provide operational data on limited IFR operations in the H34 and Hueys, and make that available as a base, we think we can greatly expand IFR as a way of life and get the kind of attention it deserves from the FAA and the regulatory agencies.

COL. GILBERT: Thank you very much, Dick.

Our next speaker is Rod Taylor from Hughes. Rod, after having obtained his advanced education in 2 or 3 places, first Northrup Institute of Technology, and later on with the University of California and University of Michigan, got started off on the right foot – he spent a couple of years with the Army down at Fort Rucker. For the last 12 years he has been with the Hughes Tool Company where he has had a number of responsible positions. He is kind of a funny guy in one respect; he takes a busman's holiday and goes for a ride. He works on airplanes all week, and on weekends he makes radio controlled model airplanes and flies them around, so he is fully dedicated to aviation. Rod:

RODNEY TAYLOR
HUGHES HELICOPTERS

Thank you. I'd like to begin the day by telling you about another name change. Yesterday we talked about the name change for the flight director. For the 12 years that I have been with Hughes, we have been trying to get our name across to the public -- Hughes Tool Company. I guess we didn't succeed, so now it's going to be changed. Those of you who have been following the Howard Hughes episodes in the paper have been aware that he recently sold the Hughes Tool Company and also the Hughes Tool name and for about six weeks we have been an unnamed division of the SUMMA Corporation, which is a new organization set up to head all of the Hughes operations that he still has under his control, such as Hughes Airwest, the Nevada operations and our own operation, so the other day we got our new name. It's a very imaginative name. We're called Hughes Helicopters. Maybe people can learn that.

Regarding the name SUMMA, several people have asked what that meant and I think the best description came from one of the fellows in our shop. SUMMA – it's an acronym that means Save Until More Money Arrives.

One of the advantages of being last on the program is that you can leave out all the stuff that has already been covered regarding your operations. I've been very interested in this conference. I think it has been a very worthwhile get together and I think that much good is going to come out of it. I was particularly interested in the comments that have been made regarding the OH-6 which has been a product very close to me ever since I have been in the business. I have been with Hughes since the day the first lines were drawn on the OH-6 and I have been deeply involved in the program ever since.

The Aerial Scout program, as you are aware, was a program to further develop the OH-6 and OH-58 helicopters. The Aerial Scout program had requirements to upgrade those two aircraft to provide full IFR capability. Several pieces of equipment were being developed; unfortunately the program has been temporarily delayed. Those pieces of equipment are available and I was delighted to hear George McMannus graciously offer to allow us to test one of them. As it has been noted, one of the key items in providing IFR capability is the increase in stability required in the aircraft itself. This obviously will add complexity to the OH-6. The OH-6 was originally conceived as a very simple aircraft with a minimum of systems and a minimum of equipment on it. Therefore, it had an unboosted control system with its attendant problems as pointed out yesterday by Major Griffith and as a result, in order to provide the stability required for IFR flight, it will require an automatic stabilization system of some sort, and a flight director.

There are other devices currently in work at Hughes to enhance the stability of the aircraft and they're directly related to some of the drawbacks that have been noted in the flight test program by ASTA. Major Griffith noted that some of the most significant flying qualities shortcomings of the OH-6 were the lack of directional control centering and the tendency of the collective control to creep in flight.

Hughes has recently developed a couple of devices that are so amazingly simple that you wonder why people haven't thought of them before. One of these devices is the pedal force compensator which is being evaluated by ASTA at the present time. This device is simply a small pneumatic actuator which is plumbed directly to compressor discharge pressure from the engine. Since compressor discharge pressure is a function of the power being extracted from the engine, the position and the force of the actuator is relative to the power being used. The actuator, in turn, is tied into the pedal control mechanism and it provides a centering – a variable centering, if you please, for the pedal control system.

Comments were made yesterday about test organizations and how, by their nature, they are quite critical; they're paid to be critical. This is also typical of the Hughes flight test organization. I receive copies of reports on R&D programs and recently when this pedal force compensator was tested, I began to receive a series of pilot flight reports which sounded like they were written by the sales department. This is an unusual situation. When I read them, I had to see for myself. I went for a demonstration ride. First thing the pilot did was lift the helicopter into a hover about 10-foot skid height, stabilize heading, plant his feet on the floor and then he did a throttle chop, a hovering autorotation with his feet planted on the floor. The aircraft's heading didn't vary more than 10 or 15 degrees in this maneuver. He then lifted up to hover again and after stabilizing the heading, made a maximum performance climb-out, reduced power to cruise, increased speed to V_{NE}, entered the pattern, made an autorotation to the ground, all with his feet planted on the floor. Now maybe you can do this with other machines but you couldn't do it without the pedal force compensator on the OH-6. This little device, I'm sure, will do much to correct the directional control centering problem that was experienced by ASTA and I think they will have good reports on the testing that they're doing on this device at the present time.

The same concept is being used now in another development program on the collective system. The collective system is also unboosted and feedback force comes from a combination of effects, mechanical as well as aerodynamic. By using this pneumatic actuator which will apply force proportional to the power extracted from the engine, the collective bungee system will only have to balance out the steady forces. The varying forces will be taken care of by the actuator and as a result, there will be far less tendency for the collective to creep which will require less friction to lock it down and thus make power changes easier and more precise.

Other areas of development at Hughes relate to things which Paul Theriault was discussing today. In fact, I am a little surprised that more comments have not been made concerning this and I would like, for one, to suggest that a future conference of this nature be held to discuss night flight by the use of IR systems. This is a brand new field that is developing, mushrooming; much technology is already available and much is yet to be developed and I think there could be much good come from another conference of this type to discuss the use of night vision equipment.

The Aerial Scout program as those of you who are acquainted with it know, required two IR systems, one for the observer which was a two-field of view device primarily used for targeting; the other, the pilot system, enabled flight of the aircraft under "inkwell" conditions that were described by the Navy. Because of our proximity to the Hughes Aircraft Company, who are deeply involved in the IR business, we have done some flying with FLIR devices. The particular device that we used has a 60-degree field of view, not as wide as Paul was indicating was necessary, but with a 60-degree device, we found that in a very short period of training, the pilot could be trained to fly the helicopter strictly by reference to the two-dimensional display. He could hover over a spot; he could take off, cruise, do terrain avoidance at altitudes as low as 100 feet and possibly below that with additional training. He could make steep approaches, normal approaches and land on a desired spot. He could also navigate down narrow canyons, fly nap of the earth and make pinnacle landings strictly by reference to the FLIR. I think this device, although it is not necessarily meant to enhance IFR flight in the clouds or under icing conditions, does take care of flying in darkness. I think it has much benefit for Army aircraft and it's a field that greatly needs development and I think we will be offered much as a result. Thank you very much.

COL GILBERT: Thank you very much, Rod.

I guess this is the first official gathering where we have been able to hear from the Hughes Helicopter Company. Moving on now to Tom Sanders from the Boeing Vertol Company. After having attended Wichita State in Kansas, it is not surprising he went to work for the Boeing Company in Wichita, where he worked on the big bombers – B-47 and B-52 – for several years. However, a more direct immediate interest to us is that he has been with helicopters for the last ten or eleven years and most of his experience in helicopters has been in the avionics, electronics and flight control areas. His present principal endeavor is related to the heavy lift helicopter where he does have the responsibility for the advanced flight control system in that bird. Tom, it's your ball.

THOMAS H. SANDERS
BOEING-VERTOL

Thank you, Colonel. Last night as we went home, I was in a state of mental shock. All day long I heard everybody steal my thunder, so last night, I had to go to the hotel and regroup. I think I have something interesting for you anyway.

First slide, please (slide 1)

The data on this first viewgraph relates to the Heavy Lift Helicopter (HLH) ATC Program. This data was taken on the flight simulator in the fall of 1971, during the first phase of the flight control system ATC. This phase dealt with concept selection for the HLH aircraft, and a concept that we will demonstrate in the Boeing Model 347 airplane.

Now just a word about what the ATC is ATC stands for Advanced Technology Component program. There are four ATC's. First, the transmission and upper controls, the blades, the cargo handling system, and the flight control system. There is now a second contract for a prototype HLH.

The data is simulation evaluation of candidate flight control systems or flight control laws from basic airplane through rate feedback, attitude, linear acceleration, high gain DCP, differential collective pitch, low gain DCP, and a low gain longitudinal cyclic system. The pilots evaluated the simulation using a Cooper Harper rating. The task was approach to hover from 300 feet out, 125 feet to the right and 200 feet above the hover point – hover at 100 feet. Now you can see as we go from the basic aircraft to the most sophisticated system that the pilots gave better ratings. As a matter of fact, based on this and other studies, a linear velocity system was recommended. The point I wish to make is that augmentation can improve handling qualities to any desired or required level.

Next slide, please (slide 2)

Boeing's 347 demonstration flight control system, which was a joint Army-Boeing program, contained the control laws very much like the third column on this chart. Boeing's management directed the flight control engineers to make a step improvement in handling qualities. When the system was evaluated, it received ratings as shown on the second chart. The engineers were shooting for a rating of threes and twos and they actually received a handling qualities rating of one for the static longitudinal stabilization. The 347 demonstration system was installed in a CH-47C. When evaluated by the professional evaluation pilots, it received ratings as shown in the second column.

Using my knowledge of the HLH ATC Program, the 347 Demonstration Program, the TAGS, and the Advanced Concept Program at M.I.T., I will go out on a limb. I believe that if given a requirement, the industry can deliver the handling qualities that the Army requires for a task or a mission. If the Army requires long term, hands-off stability in order to do a task and/or mission, it can be provided. The technology is here today; it is here in the airframe industry; it is here in the flight control system electronic industries. What we need is a stated requirement for handling qualities.

I was really pleased yesterday to hear Mr. Lewis and others say that in the future, specifications will recognize the helicopter type and its mission and tasks. When this happens, the proper augmentation to provide the necessary handling qualities can be supplied.

Next slide, please (slide 3)

General Maddox talked about Firebase 21 yesterday. He used the words "pinpoint operation;" he spoke of "continuous coverage;" and he said "don't get divorced from the terrain." In the HLH ATC, we have these kinds of objectives. On this viewgraph, you will see an excerpt from the work statement. Without visual reference to the ground, position the helicopter and external load within 4" of a reference point at a hover altitude of up to 100 feet, provide hands-off hover capability to maintain hover position to ±4" in X, Y, and Z, and from 300 feet altitude and 200 feet horizontal distance, position the helicopter in 2 minutes. These objectives tell me that the Army wants to get down into the muck and operate in natural or induced obscurations. The control laws we are developing for the HLH demonstrator will provide the handling qualities for this type of operation.

Although I am impressed with the presentation, debates and arguments about 2-cue and 3-cue flight directors, I think that this type of equipment, per se, misses the ballpark. The helicopter needs to stay and do a task in places where the outside world is not sophisticated enough to provide the signals that the flight director requires.

The HLH ATC will utilize a ground speed velocity reference for the low and slow operations. This will relate the helicopter control to the ground, not the air mass. A sensor sorely needed is an inexpensive inertial or ground velocity measurement unit. The navigation type inertial systems are too expensive. I was pleased to hear about the helicopter doppler system that Teledyne Ryan mentioned. A sensor that is needed for low, slow operations under obscuration is an obstacle avoidance system. This device will provide a warning of obstacles that could contact the rotor blades. It would have a range of a few hundred feet, compatible with velocities of 10 knots or less. The flight control system can provide the handling qualities to make low, slow instrument flight feasible and such a sensor can provide a feeling of safety.

Next slide, please (slide 4)

This slide shows the HLH flight control system basic elements. It is a fly-by-wire system and contains two principal parts. First is a direct electrical linkage system. This element is an electrical analog of the conventional push-rod, power boost, mechanical control system. The second part is an automatic flight control system. This element will provide the handling qualities. The direct electrical linkage is multi-redundant and the automatic flight control system is a multi-redundant system utilizing digital computers. On the viewgraph, you can see the types of feedback; angular velocity, angular position, linear acceleration, linear velocity, linear position. The linear position feedback is provided by a precision hover sensor. This is the system that will provide the ±4" hover hold. On this point, I find that I am often misquoted. The 4" hover hold is not a specification for a production HLH, it is a task within the ATC where the extreme accuracy will be evaluated. During the demonstration, we intend to degrade the position capability to find out where the payoff stops.

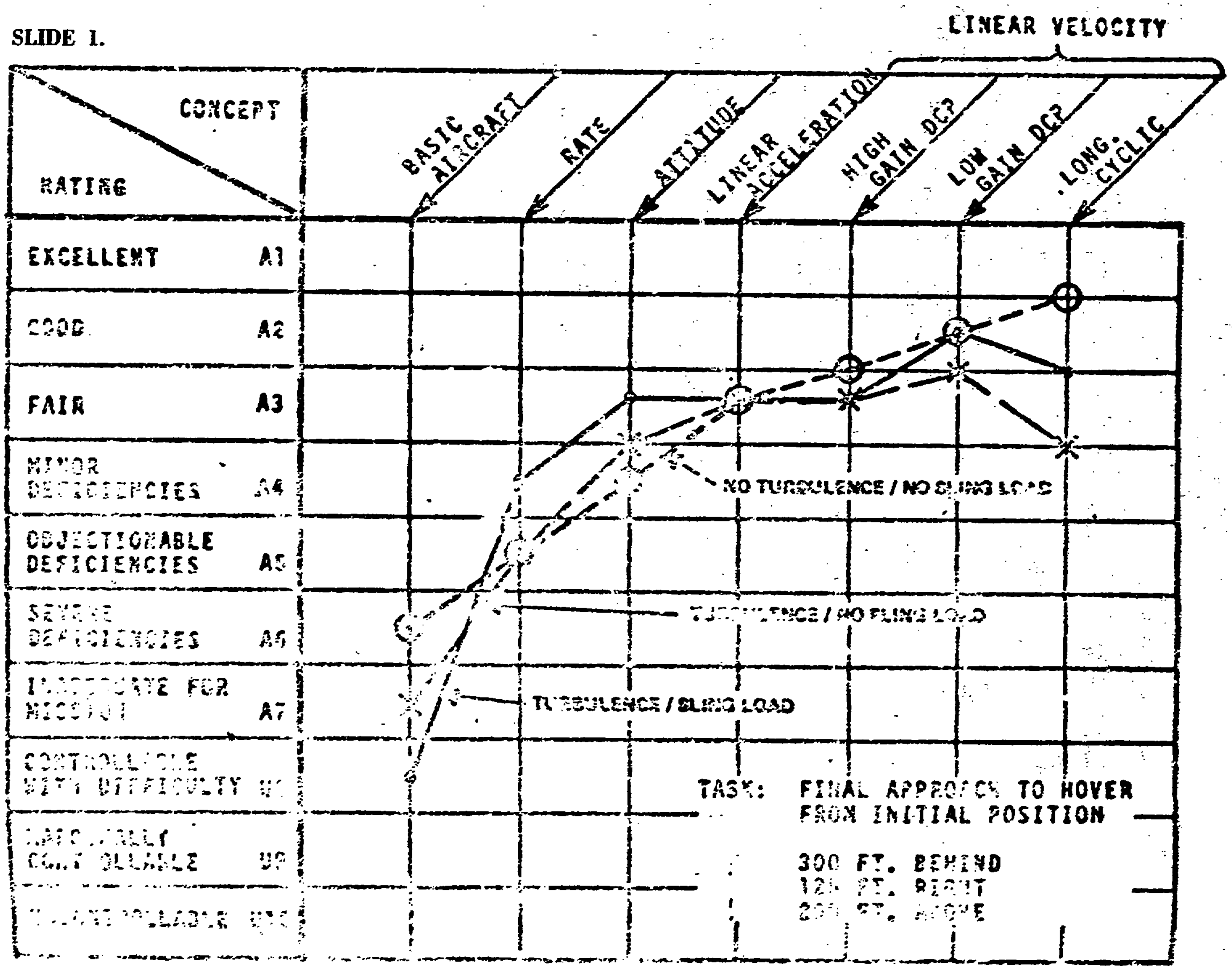
Next slide, please (slide 5)

This viewgraph shows that I wasn't kidding about all that was said yesterday. You heard the same thing several times. I do believe that handling qualities requirements should be stated in the helicopter system specifications. For the people who test helicopters, I believe you are going to have procedures that relate to the black boxes that provide control augmentation and I further believe we are going to have to evaluate performance against specific tasks and mission requirements.

HLH FLIGHT SIMULATION

QUALITATIVE EVALUATION OF CANDIDATE CONCEPTS

SLIDE 1.



	HQRS	
	347 DEMO. SYSTEM	CH-47C MODIFIED SYSTEM
SLOW FLIGHT AROUND HOVER	--	2
TRIMABILITY IN FORWARD FLIGHT	2	2
STATIC LONG. STABILIZATION	1	2
STATIC LAT. DIR. STABILIZATION	4	3
DYNAMIC STABILIZATION	2	1
MANEUVERING FLIGHT	3	--
CONTROLLABILITY	2	--
TURN COORDINATION	2	1

SLIDE 2.

HEAVY LIFT HELICOPTER (HLH)

ADVANCED TECHNOLOGY COMPONENT (ATC)

GENERAL OBJECTIVES:

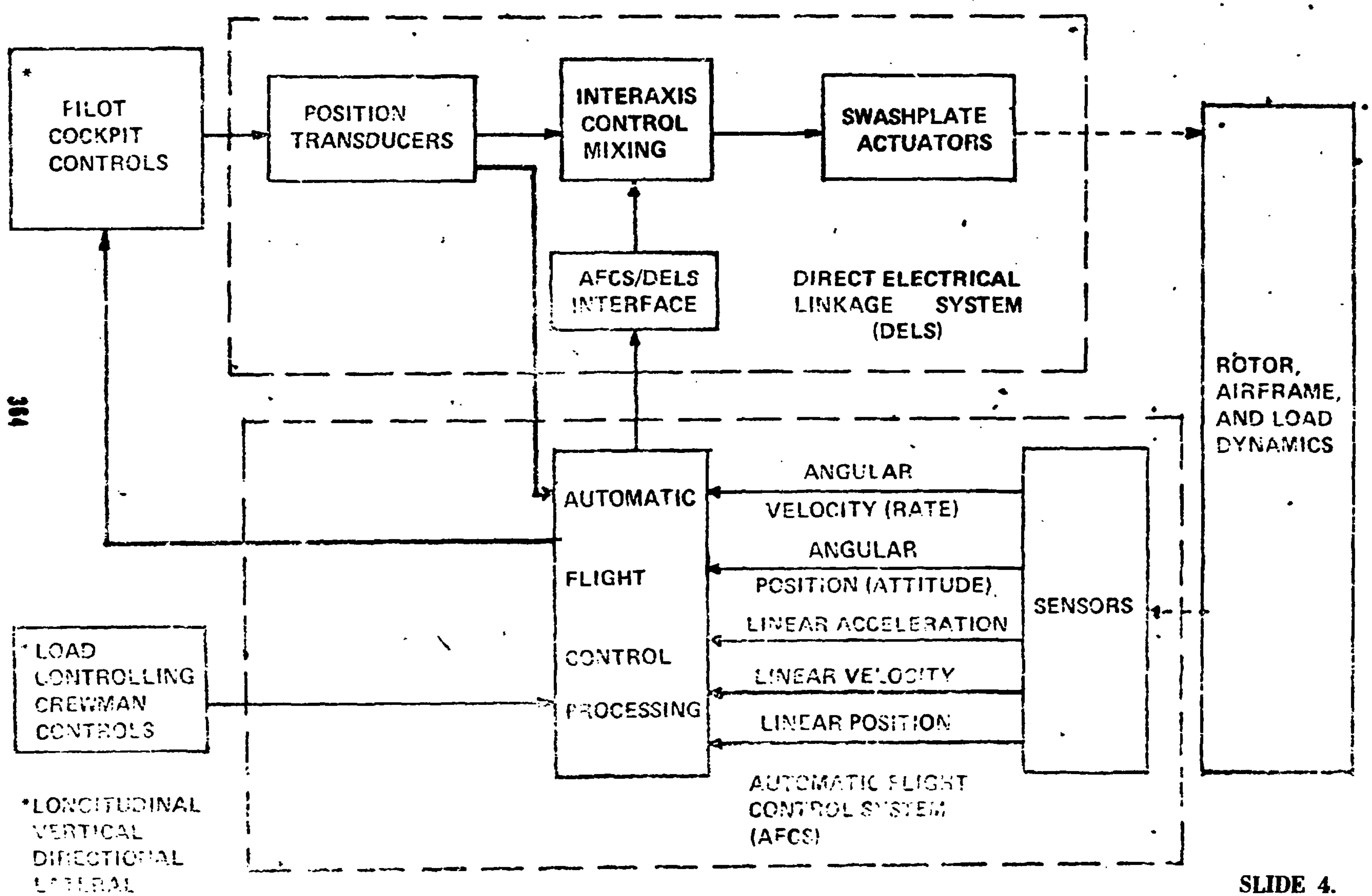
- FLY-BY-WIRE
- OPTIMIZE HANDLING QUALITIES
- FLIGHT SAFETY RELIABILITY: 0.9999999
- MISSION RELIABILITY: 0.99962

SPECIFIC INSTRUMENT FLIGHT OBJECTIVES:

- WITHOUT VISUAL REFERENCE TO GROUND
  - POSITION HELICOPTER AND/OR EXTERNAL LOAD WITHIN 4 INCHES OF A REFERENCE POINT AT A HOVER ALTITUDE UP TO 100 FT.
  - PROVIDE HANDS OFF HOVER CAPABILITY TO MAINTAIN HOVER POSITION TO ±4 INCHES, X, Y, Z.
  - FROM 300 FT. ALTITUDE & 200 FT. HORIZONTAL DISTANCE, POSITION HELICOPTER IN 2 MINUTES.

SLIDE 3.

HLH FLIGHT CONTROL SYSTEM BASIC ELEMENTS



SLIDE 4.

FUTURE NEEDS

1. REQUIREMENTS THAT EXPLICITLY AND RIGOROUSLY RECOGNIZE STATE-OF-THE-ART IN STABILITY/CONTROL AUGMENTATION, AND
2. STATED IN TERMS UNIQUE TO AND OPTIMUM FOR A GIVEN HELICOPTER TYPE AND ITS MISSION TASKS.
3. TEST CRITERIA AND PROCEDURES APPROPRIATE TO "BLACK BOXES", COMPUTERIZED ELEMENTS, LOGIC, REDUNDANCY, ETC.
4. HANDLING QUALITIES TEST CRITERIA AND PROCEDURES FOR UNIQUE TYPES AND THEIR MISSIONS AND TASKS.
5. LOW COST, NEAR ZERO DRIFT GROUND SPEED VELOCITY SENSOR.

SLIDE 5.

COL GILBERT: Thank you very much, Tom.

I think he almost talked himself into a corner at one point. He said he thinks technology is here in most any area if he can get a specific requirement. About two minutes later, we saw a slide looking for 4 inches hover accuracy at 100 feet. That is pretty specific and I think Boeing has got its work cut out on that ATC program.

Our last speaker from the industry side of the house for this panel is John Kidwell of Bell. John got his advanced education at the University of Kansas and then he got some further advanced training at the Army right here at ASTA. Then for the last several years he has been at Bell on a variety of rotary wing programs and he is presently at work on test and evaluation at Bell. John:

JOHN C. KIDWELL
BELL HELICOPTER COMPANY

Thank you, Colonel Gilbert. Everyone here today, I think, is familiar with the configuration of our basic UH-1 series helicopters that we build at Bell. We have an approved configuration of the aircraft – certified by the FAA for certain operations on the airways. I'd like to show you that configuration and outline some differences.

First slide, please (slide 1)

This is a picture of the aircraft as it was certified. It is a Model 212, civilian commercial model aircraft, twin engine, and the most noticeable difference between this aircraft and our typical UH-1 configuration is what we call the sail. This structural fin was added to the aircraft in response to the FAA requirement for certification of the 212 to provide positive dihedral stability in all flight regimes.

Next slide, please (slide 2)

This pictorial schematic shows the things that were done inside the aircraft that are different from our basic UH-1 series to get an IFR configuration. It includes the sail and numerous black boxes that went into the makeup of our stabilization system which includes a SCAS, attitude retention in roll and pitch and directional heading hold. There are several linkages and mechanisms that are not in the basic UH-1.

Next slide, please (slide 3)

Another thing that was done in the program was an attempt to take out the effects of power manipulation in all axes, laterally, directionally, and longitudinally. It was done by mixing a mechanical collective signal through a scissors linkage for each axis, and feeding it into the control system. The yellow graph indicates our goal, which was to achieve collective change throughout the range without cyclic or directional control movement. A measure of how well we succeeded is on the next slide.

Next slide, please (slide 4)

Our fore and aft trim change going from full autorotation to 1400 feet per minute of climb for the regular Huey was 15 percent and with the addition of the scissor linkage mixing linkage coupled to the collective, it was 3 percent. Similarly, we reduced the lateral excursion from 22 to 5 percent, pedal excursion from 32 to 5 percent, so we made a large improvement with this mechanism added to the aircraft. The chart on the right shows a somewhat smaller excursion in power from 800 feet per minute rate of sink to 1100 feet per minute rate of climb. We did achieve fairly minimal trim changes with this configuration, with collective motion.

Next slide, please (slide 5)

The flight control system, as I said, provided for attitude stabilization in pitch and roll and heading hold. It also provided the function similar to the SCAS that the military aviators are familiar with in our AH-1G series. This is a schematic of the controls that were anchored in the aircraft through the standard spring cartridge with an actuator that replaced our standard centering brake that we have on the Huey series aircraft.

Next slide, please (slide 6)

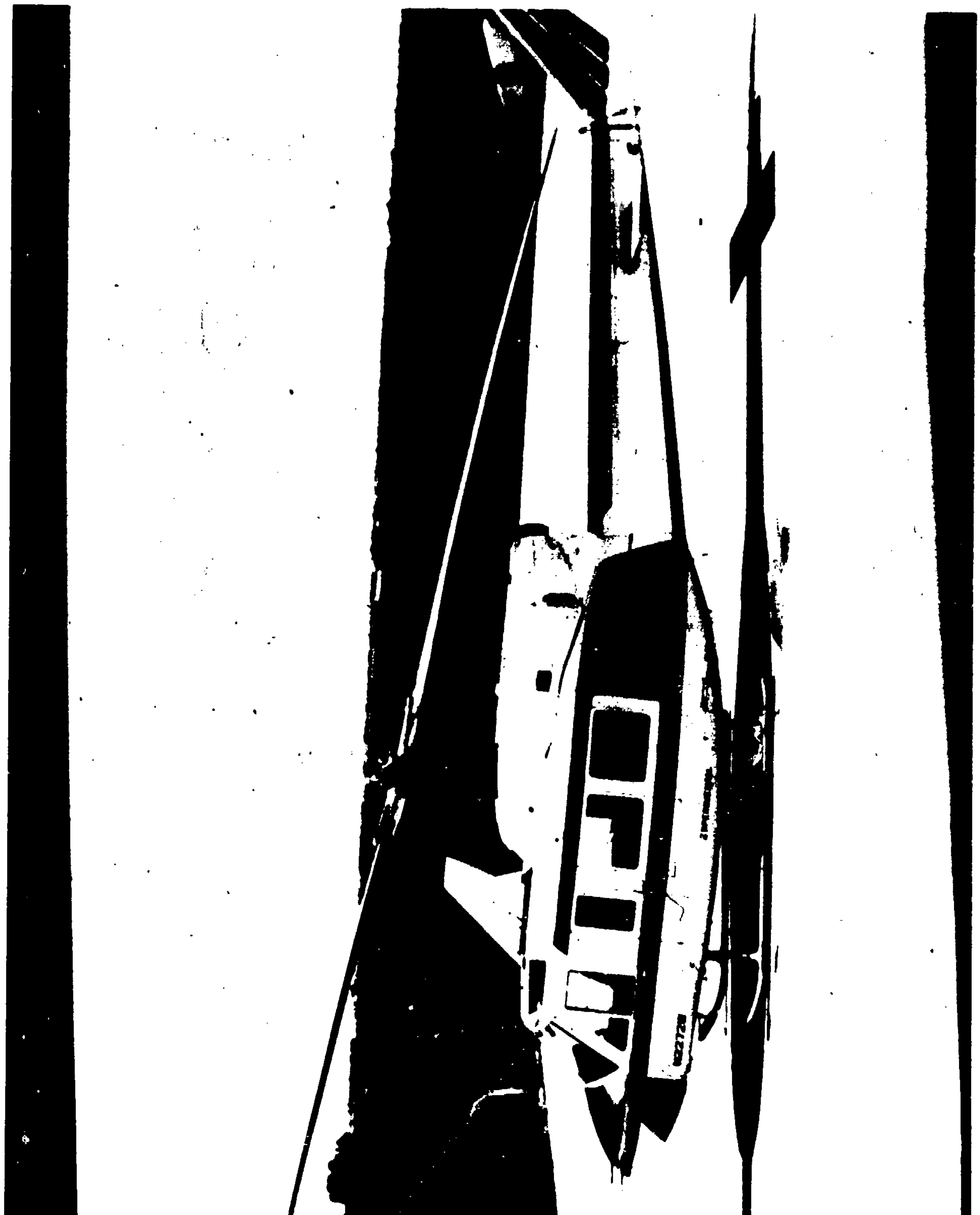
The stick grip functions are similar to the UH-1, but this time we did get a trim function on the coolie hat, nose up, nose down, left and right similar to fixed wing aircraft. The rest of the functions are very similar except for the SCAS and AFCS disengage button.

Next slide, please (slide 7)

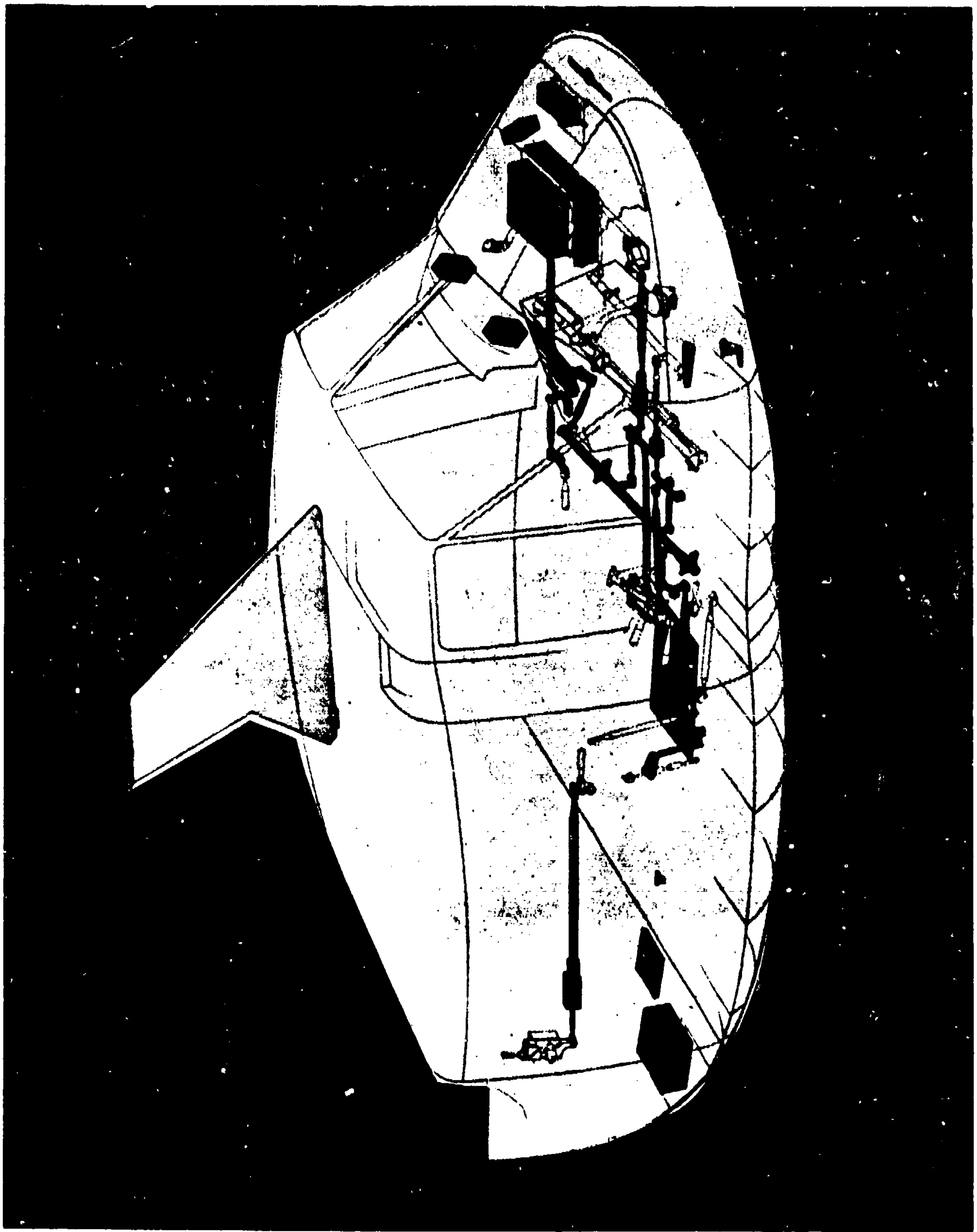
This is the cockpit layout that resulted from the certification program and I don't think it looks too frightening judged against the standard multi-engine aircraft cockpit. The controls for the automatic flight control system are in this area. There is one bit of redundancy in the cockpit in that the condition lights for the automatic flight control system are duplicated for the pilot so that his field of vision includes the condition lights. While this aircraft, as I have described it to you, does not represent a tactical configuration that meets some of the needs we have talked about during the last couple of days at this meeting, it does represent a milestone to us in that it is an aircraft that is FAA approved for airways operation within the continental United States and it is not the standard UH-1 configuration aircraft.

Slide off, please

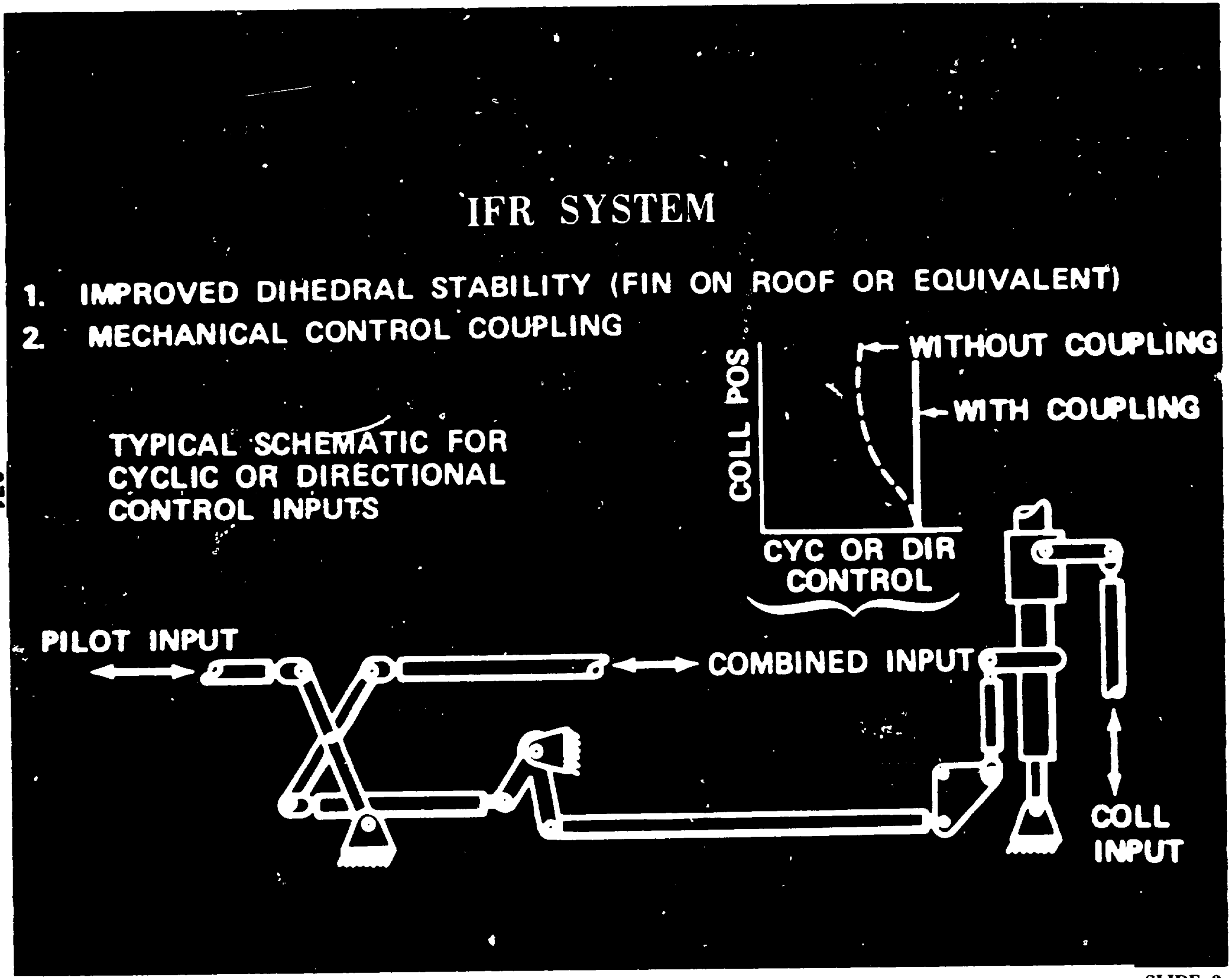
Future programs are going to include additional certification work with the FAA, looking at the requirements and perhaps simplifying the configuration I have described.



SLIDE 1.



SLIDE 2.


IFR SYSTEM
1. IMPROVED DIHEDRAL STABILITY (FIN ON ROOF OR EQUIVALENT)
2. MECHANICAL CONTROL COUPLING
TYPICAL SCHEMATIC FOR CYCLIC OR DIRECTIONAL CONTROL INPUTS
COLL POS
WITHOUT COUPLING
WITH COUPLING
CYC OR DIR CONTROL
PILOT INPUT
COMBINED INPUT
COLL INPUT

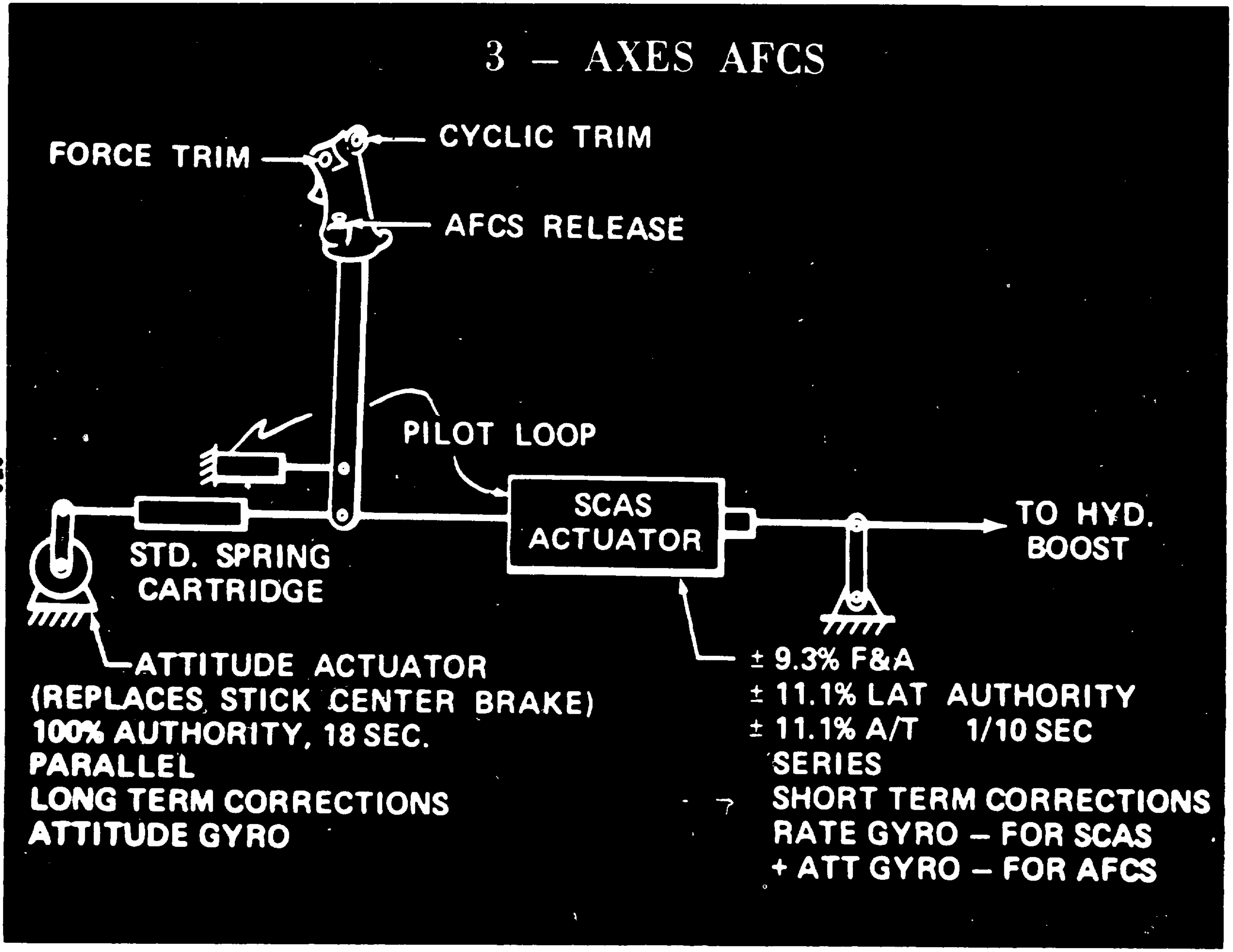
SLIDE 3.

COMPARISON STD VS COUPLED CONTROLS – 100 KNOTS

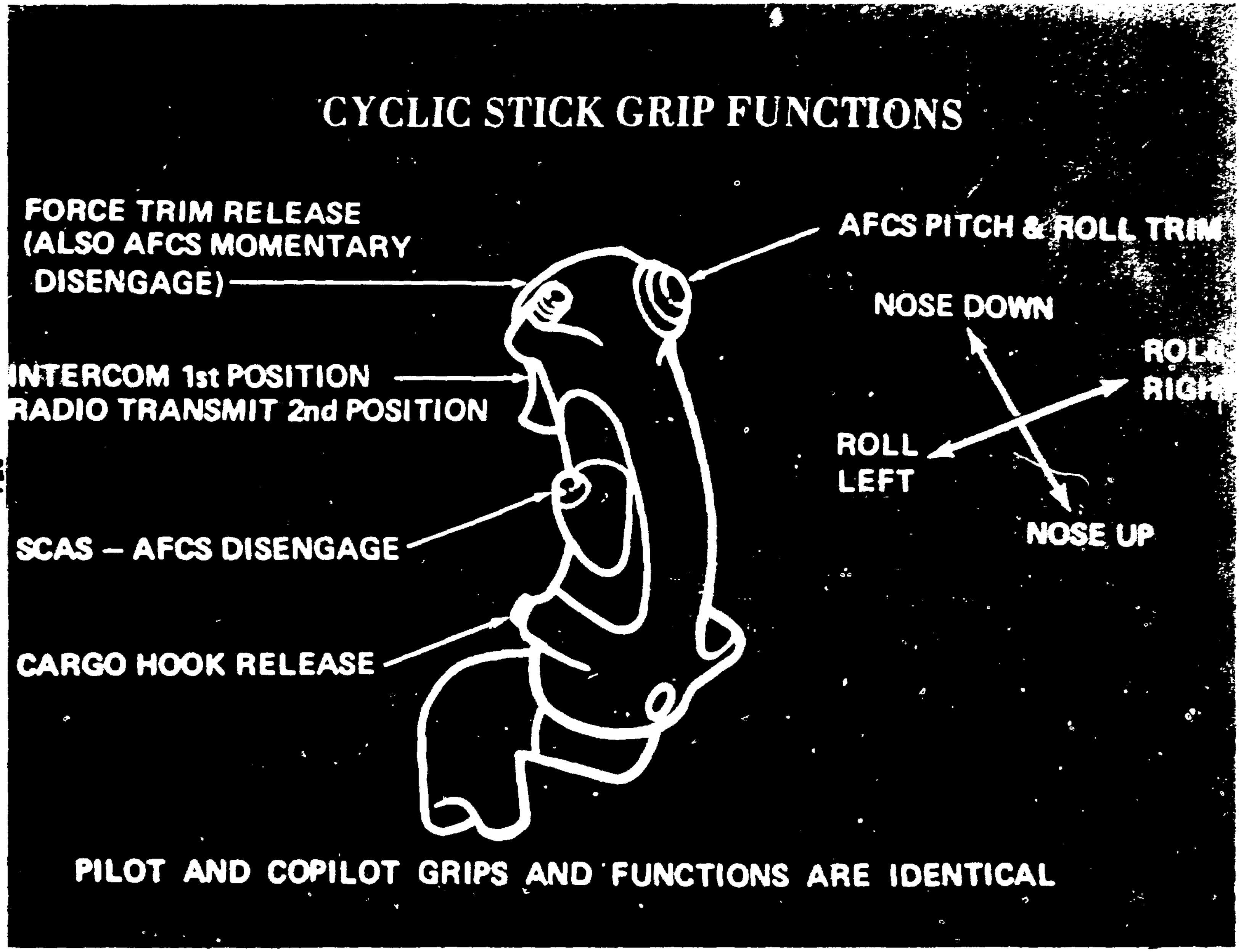
% TOTAL PILOT INPUT

	FULL AUTO TO + 1400 '/M			-800 '/M TO 1100 '/M		
	STD	IFR	% REDUCTION	STD	IFR	% REDUCTION
F & A	15%	3%	80%	8%	2%	75%
LAT	22%	5%	77%	12%	3%	75%
PEDALS	32%	5%	84.5%	21%	4%	81%

SLIDE 4.

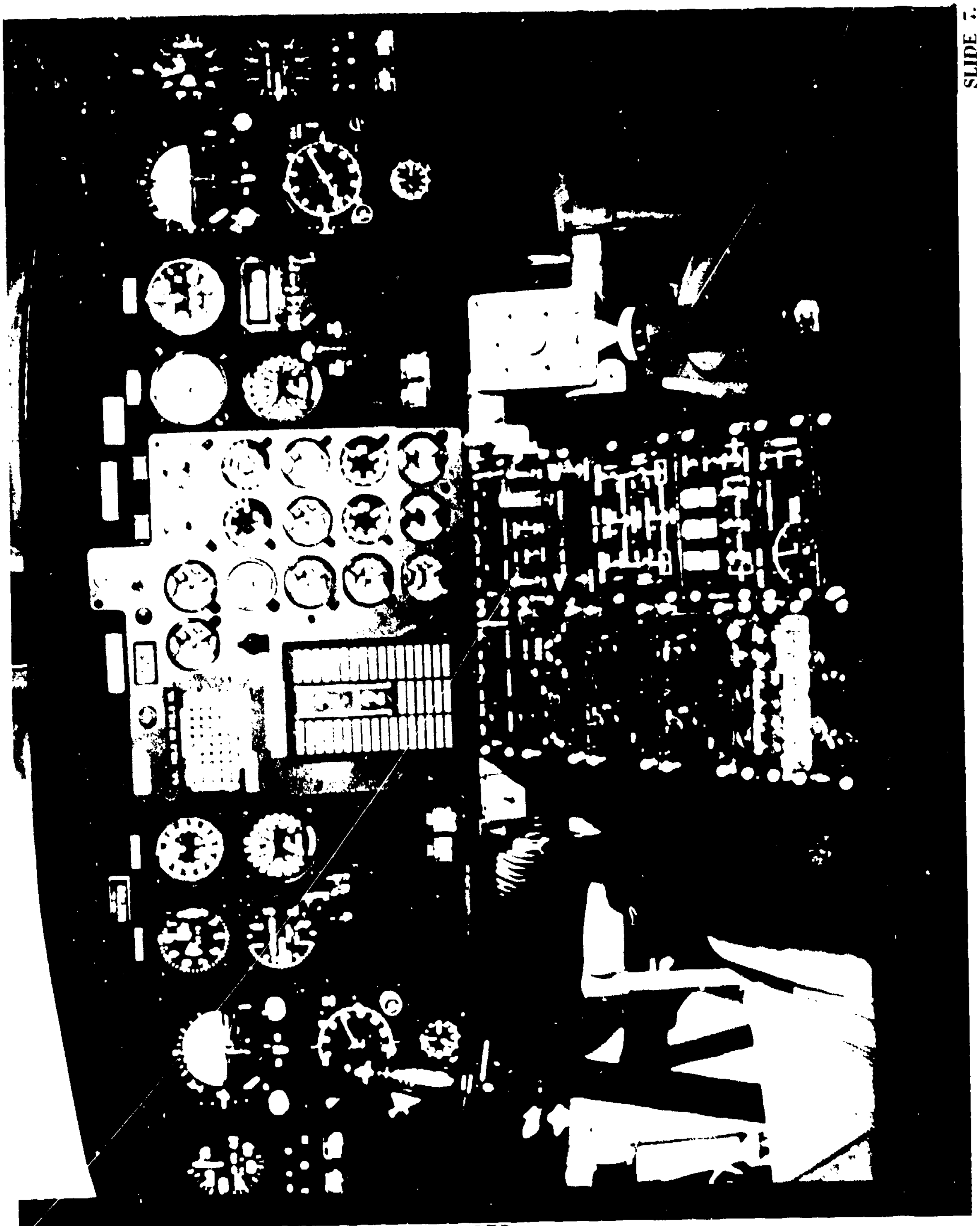

3 – AXES AFCS
FORCE TRIM
CYCLIC TRIM
AFCS RELEASE
PILOT LOOP
SCAS ACTUATOR
TO HYD. BOOST
STD. SPRING CARTRIDGE
ATTITUDE ACTUATOR
(REPLACES STICK CENTER BRAKE)
100% AUTHORITY, 18 SEC.
PARALLEL
LONG TERM CORRECTIONS
ATTITUDE GYRO
± 9.3% F&A
± 11.1% LAT AUTHORITY
± 11.1% A/T 1/10 SEC
SERIES
SHORT TERM CORRECTIONS
RATE GYRO – FOR SCAS
+ ATT GYRO – FOR AFCS

SLIDE 5.


CYCLIC STICK GRIP FUNCTIONS
FORCE TRIM RELEASE
(ALSO AFCS MOMENTARY
DISENGAGE)
INTERCOM 1st POSITION
RADIO TRANSMIT 2nd POSITION
SCAS – AFCS DISENGAGE
CARGO HOOK RELEASE
AFCS PITCH & ROLL TRIM
NOSE DOWN
ROLL
LEFT
NOSE UP
PILOT AND COPILOT GRIPS AND FUNCTIONS ARE IDENTICAL

SLIDE 6.

SLIDE 7



COL GILBERT: Thank you very much, John.

That concludes the brief remarks by our contractor panel members and I thank all of them very much for their kind and generous remarks to this audience. I was just totaling the number of years represented by these five guys and it comes right at 100 years of experience sitting here. I think that is symptomatic of the audience that we have as well.

It's been a good experience for me and a very impressionable one to see the broad range of expertise from industry and from within the government represented here and the contribution that all of them made to this conference. I would just make one closing remark as far as this panel is concerned prior to turning it over to Charlie. It's very apparent that technology has progressed; that we can define what we really need to do as opposed to what we think we would like to do or might desire to do; can employ the systems approach that has been stressed by a number of our panelists both on this panel and previous ones and come to an acceptable balance between technology and what it can offer versus the economics and the safety that goes along with it. I call upon the continued innovative thinking on the part of industry as well as the government agencies involved. I intentionally say government agencies – as opposed to Army – because it's obvious there is considerable expertise throughout this great country of ours – both within the government and within industry. Charlie, with that I'll pass it back to you to adjourn this conference.

SUMMARY AND CLOSING REMARKS

MR. CHARLES C. CRAWFORD
US ARMY AVIATION SYSTEMS COMMAND

I guess I'll have to be "Leroy" again to close this meeting. One of our objectives in setting up this conference was to limit it to a day and a half so that those people that are real busy on the East Coast would have an opportunity to get back there today and only be gone two days. With that in mind, I'm going to be very brief in summarizing.

Looking back over what we have discussed, I want to emphasize one point relative to the ASTA efforts that were debriefed here for your benefit. These debriefings had to be critical in nature in order to serve their function and we certainly realized and we hope that everyone in the audience realized that it was not the purpose of these debriefings to condemn any piece of equipment or to give any particular piece of equipment or total aircraft system an advantage in future marketing over any other. It was just an honest assessment of the results of tests that they had conducted to determine how well the three specific helicopters stood up in performing missions for which they were not designed. I think it's very important that everybody in the audience who may not know the history of the LOH program understands that neither of these aircraft were designed for any instrument flight operations whatsoever. From the standpoint of the findings of the tests conducted with the Crane I think we are gratified to learn that the Crane will be successfully operated under IFR conditions. I want to point out that this is something that we think can happen notwithstanding the fact that the aircraft does not meet the "specs." There were two very different diversified areas in which they did not meet the specification. The control system didn't meet the standard for the force requirements and the damping of the aircraft itself did not meet the IFR standards. On the other hand, the prediction is that the aircraft can be very successfully operated IFR. This, of course, is aside from the icing considerations. This does lead to the positive indication that the "specs" are inadequate. We will do the best we can to get an adequate specification.

From the standpoint of summarizing other aspects of their work, I personally concluded that SCAS or SAS or a comparable system makes a greater contribution than a flight director. I think that a dedicated flight director system for a helicopter will be a great asset. There are two very good features that stood out in these talks as far as things that would apply to a dedicated helicopter system. One was the 3-cue situation as opposed to other applications for fixed wing aircraft, and the second is the deceleration features that were discussed in detail. Those kinds of features in a flight director system may well be the key to the future successful operation of helicopters with one pilot. One-pilot operation is extremely important from the standpoint of life cycle cost and cost of training. The actual cost of reoccurring training in the life cycle picture of an Army team is quite high. On the other side of this flight director coin, we have got to look more carefully into the concerns that the NASA people offered. They summarized their concern about inherent disadvantages in flight directors from a fixation point of view. I think before the Army goes into procurement of this type of equipment, this is something we have got to look into.

From the standpoint of things that we learned from our other services, two stand out. One considered the automatic flight control system a must. Secondly, both were very loud and clear on the two-pilot requirement. Another very interesting point came out of some of the discussion summarizing the efforts that had been done at Randolph. I recall a statement that was made, something to the effect that a detail effort in adequate cockpit design could have effects as high as a 75-percent increase in mission effectiveness due to a reduction in pilot workload. I really appreciated the points that they're making relative to flight control systems and relative to two-pilot operations.

The overall opinion that I received from the message of the FAA was that they feel to ensure safe operation of helicopters under IFR, they essentially need to fly like a fixed wing airplane. I personally do not agree with that. I personally feel that the two-pilot requirement of other services and the fly-like-a-fixed-wing-airplane of the FAA may not be giving the helicopter as much credit as is really due. If you go back over what the services and what the commercial operators have done with helicopters over the years, the helicopter has always been the most flexible of all aerial vehicles and if we can make some progress at flying them in bad weather, it is my personal view that the helicopter or a machine with comparable flight path capabilities will always remain the aerial vehicle with the most flexibility. I think that the helicopter isn't getting all the credit that it deserves from the standpoint of flexibility and we may be a little bit hard on the pilot requirements in doing so.

There is one area where the military has got to get on the ball and this is, we have got to define the various levels of IFR that we are talking about. When one speaker gets up on the stand, he mentioned IFR, he has a point of view; the next speaker had a slightly different point of view. We have got a wide range of problems to solve. We have got the range of problems of just enroute IFR operation of a Cobra to get it from point A to point B so it can hook up with some other unit and start fighting. That might be the simplest problem we have to the more difficult problem of actually engaging and destroying the enemy under weather conditions where you cannot see the gun. This goes far beyond flying qualities or equipment on board a helicopter; it gets into the kinds of weapons. I don't mean to get into the area of discussion, but we simply have got to define some specific levels of operational capability which the military needs and spell these out to industry so they can meet these kinds of design requirements. I think the second thing that we need – the thing that we need to do in laying these levels of IFR operation out, is to be very conscious of the impact that these levels will have on the kind of equipment and the number of pilots because of the large impact of training the crews. The overall effort to remain proficient in helicopters is a little bit greater than in fixed wing and that should shed more light on the importance of the training problem. The last point that I'd like to make is that we definitely need a significant increase in emphasis on helicopter dedicated approach systems. I made the point earlier that in my personal view, the most flexible of all aerial vehicles is, in fact, a helicopter. Yet we are not capitalizing on that flexibility when you have to come in and make a T-33 type of approach to land at some particular runway. I also think that we maybe are overemphasizing the IFR operation of helicopters in CONUS as opposed to on the battlefield. The real problem as General Maddox explained is in the combat conditions, and if our helicopters can meet those requirements, they are going to be awfully attractive for the commercial operator to do almost anything that he can conceive.

I probably have left out a lot of important points. If anyone else would like to add a key point in summary, I'll open the thing up for a couple of minutes. It's a very difficult task for me to even absorb everything that has been said in the last day and a half. I sincerely hope that all of you feel that the conference was worth the cost involved.

Dennis Tuck would like to attack my comment on the FAA. Dennis, get up.

MR. TUCK: I sure would, Charlie.

I think you misunderstood what I was trying to say relative to -- none of the IFR helicopters that we have approved fly like that one. What I tried to say was that we expect IFR helicopters to either fly like airplanes or to require no more attention to fly than airplanes. Actually the approvals that we have done do not fly like airplanes but they achieved a level of stability that requires no more attention than flying a fixed wing airplane in IFR conditions.

MR. CRAWFORD: I appreciate your elaboration on the point, Dennis. Anybody else that would like to add anything to the conference?

If not, I would like to close the conference by thanking our US Army Aviation Systems Test Activity for all of the arrangements they have made. I think they have done a tremendous job in making this conference very easy for all of us to attend. I also feel that they have done a tremendous job in the evaluation of the equipment that they briefed on yesterday. They're really a hard-core element of the Army that, if we're going to ensure we achieve the right answers, we can't do without; so I can't say enough good about Colonel Wright and his ASTA team and the work they did in setting up the conference.

On the other side of the coin, I do want to make one other point. It's really following up on something Colonel Crouch mentioned when he opened the future needs discussion. We do not expect and we do not desire that this conference will result in 500 unsolicited proposals to the Army as a result of ideas that have been expressed here and I seriously doubt if the Air Force or Navy needs them either. By the same token, you must understand that the Army Aviation Test Activity cannot be a trial laboratory for every piece of equipment that the American industry can conceive relative to IFR. We have undertaken evaluation of certain pieces of equipment in order to establish a foundation, what benefits were derived from what different types of equipment. This type of work is not their fundamental mission and we are very limited in manpower and funds to expend in that direction. So while we are seeking everyone's good ideas, don't flood us with new pieces of equipment to test or unsolicited proposals solely as a result of this conference. We intended this to be an informal exchange of ideas. I think we have met that objective and I certainly appreciate everyone coming. With that we'll consider the conference adjourned.

Thank you very much.

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