# LOW-COST TRAINING TECHNOLOGY

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You heard earlier from Paul a psychologist's viewpoint of training technology. I'm a psychologist, too, but I have this hardware-software bent to me, so I'm going to talk about, I think, much more practical issues in training technology and just try to concentrate on a very few points.

You're going to hear a great deal in this workshop about technology and air crew training. I'd like to use this opportunity to point out some important differences between training technology on the one hand and the technology of flight simulation on the other. I will also describe two relatively inexpensive training systems in order to demonstrate how low-cost technology when properly applied can meet training needs. Finally, I would like to discuss the potential impact of new cockpit technology on training and, I think, some innovative approaches that are being tried to solve those problems.

In selecting systems or devices to train air crews, it is essential to understand at the outset the differences that exist between training technology and flight simulation technology.

The first distinction I'd like to make has to do with the goals of these two technologies. The goal of flight simulation technology is to design and build a ground base system that duplicates as closely as possible all of the characteristics of a particular aircraft. These include cockpit instrumentation, switches and controls, aircraft handling properties, and the creation of out-of-the-cockpit visual scenes and motion illusions.

The goal of training technology, in contrast, is to provide a tool by which certain specified skills can be developed and maintained. Physical realism or fidelity with the aircraft is only provided to the extent necessary to meet a particular training objective. To provide characteristics of the aircraft which do not support that training objective is to increase the cost of the system for cosmetic rather than training purposes.

The second major difference, which obviously follows from the first, between simulation and training technologies is based upon the perceived relationship between the device and the aircraft. It wasn't always the case, but it has come to be in recent years that flight simulators are viewed as substitutes for the real aircraft. It is not surprising, therefore, to find that pilot acceptance has come to play a key role in the evaluation of these systems.

A training device, on the other hand, is viewed as a supplement to, and not a substitute for, training and experience in operating the aircraft. It is only used to develop and maintain certain skills which are more effectively or more safely taught on the ground. As with any tool, a training device is evaluated on the basis of how well it accomplishes the purpose for which it was designed. If it is effective in meeting the training objective, it is an effective device.

Finally, training technology is concerned with improving and aiding the process by which air crew skills are learned. Instructional aids and techniques are a part of the training requirements from the outset. With flight simulators, the application of instructional technology is often, at best, an afterthought in the design process.

I've pointed out what I feel are differences between training and flight simulation technology because I think they are too often thought of as one and the same. I don't believe they are. Since the best way of explanation is by way of example, I'll provide two examples of training technology which emphasize the two key elements in training device design. First, provide the physical realism necessary to meet the training objective and, second, provide the instructional technology to facilitate the training process.

The first example of training technology I'm going to show you was developed by the Defense Department to provide alternatives to expensive new flight simulators. With annual simulator costs approaching some 300 million dollars, the need for effective alternatives is clear. One such alternative is the Navy's low-cost training system.

The Navy's goal was to develop procedures and part task trainers which were comparatively inexpensive to buy and maintain but would be just as effective in training both procedural and selected flight tasks. Cost savings of approximately 75 percent were achieved by providing realism only to the extent actually needed.

For example -- and there is a whole list of these, this is only a partial grouping of them -- cockpit configuration is approximate rather than exact. Chairs are used rather than aircraft seats. Photographs were used in lieu of actual panels. Only the most essential instruments are dynamic. Instrument needle movements are discrete rather than continuous. And redundancies are eliminated such as providing for a single engine malfunction versus all. Flight dynamics are limited to 60 degrees of bank and 45 degrees of pitch. They also included a simplified visual system to permit takeoff, approach and landing training.

The following slides show some of the characteristics of these trainers. And you can see we are down to a bare bone system here. This is the Navy SH3H helicopter. The CRT and keyboard is the instructor station. It swings forward and backward to allow for student self-programmed instruction. It is possible to use this system without any instructor at all.

The second slide is just an internal shot of a twin jet trainer. It shows a fairly good quality reproduction of the instrument systems. A field test was conducted to compare the effectiveness of these low-cost trainers with conventionally designed systems.

Approximately 50 operating procedures and more than a dozen normal and emergency flight tasks were evaluated in the trainers and in the aircraft. The results can be summarized in the words of the investigators who conducted this study. The low-cost trainers allowed training of the same content to the same level of proficiency and with equal efficiency as the more expensive conventionally designed counterpart device. Commercial applications of this approach have been applied to various aircraft such as the DC8, the 727, the 737. Clearly, despite the lower physical realism of these devices, training of the necessary air crew skills can be effectively conducted.

The Navy's low-cost training system is just one example of what can be accomplished when physical realism is provided only to the extent actually needed.

The second example I would like to provide of training technology illustrates the importance of considering instructional aids and devices that are being developed. The sheer complexity of modern aircraft systems and procedures demands a more sophisticated approach to the instructional components of training systems.

This is the interactive cockpit training device which has been developed by Flight Training Devices Incorporated, and it illustrates the wide variety of instructional technology available and how that technology can be effectively integrated into a training device.

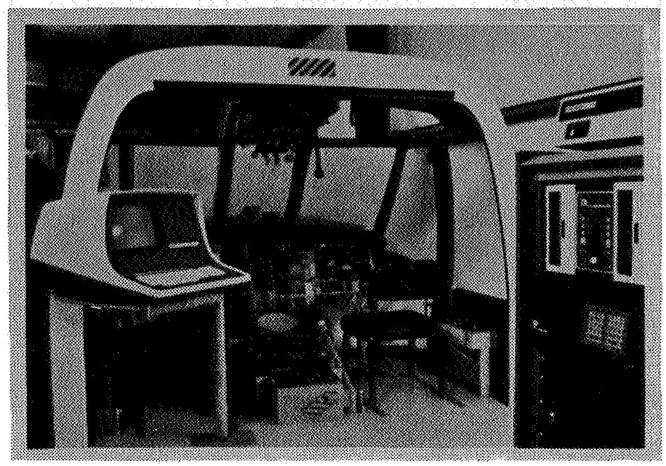

Figure 1.- Low-cost cockpit procedures trainer for the Navy SH-3H helicopter.

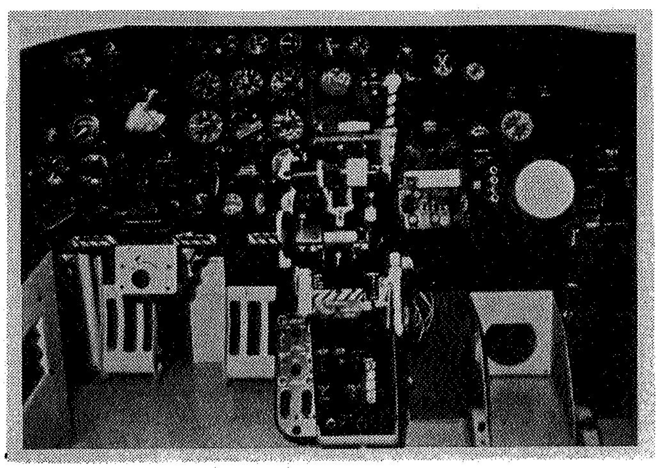

Figure 2.- Low-cost part-task trainer for the Navy EA-3B aircraft.

The system is designed as a total learning environment for systems knowledge and basic procedural skill training. It has the capacity for initial ground school, normal and abnormal procedures training and training in LOFT-oriented crew member duties and responsibilities.

(Figure 3 here)

As shown in this slide, the basic system is composed of a replica of the aircraft cockpit. The instrument panels have been replaced with photographs, and the photographs are covered with touch sensitive membranes. Control lights and dials appear as they normally would in a darkened cockpit. Two projection screens are provided, one on the left, one on the right. One for the pilot and the co-pilot. A CRT screen is mounted between them. These, too, are covered with touch sensitive membranes.

A wide variety of audio-visual devices is included to facilitate the training process. These include random access slide projectors used to show manufacturer's supplied information, computer text and graphics to display instructions to the trainee, and computer generated graphic illustrations, video disks and video tapes to demonstrate real time system operations and procedures, and random access audio to enhance the visual material and provide verbal feedback for training responses. The whole works is driven by an Apple computer which provides programmed learning sequences, controls all the audio visual presentations and monitors and records training performance.

A given training sequence may begin by introducing the trainee to basic system theory such as electrical or hydraulics. Following successful demonstration that the basic knowledge has been acquired, the students might move on to drills in locating and identifying relevant instrument controls and switches.

Normal and abnormal procedures training may follow with the computer taking the trainee through each step on the checklist. The separate duties and responsibilities of each crew member are made explicit and reinforced with audio-visual aids at this point. The training sequence ends with a final exam to make sure that the trainee has acquired the necessary knowledge and skill.

Savings in advanced flight simulator time of 20 to 25 percent have been reported by students trained on this system. Given the high cost of leasing or renting simulator time, to say nothing of the cost of ownership, this type of training technology has a potential for significant cost savings in air crew training. In addition, the system demonstrates the variety and utility of instructional

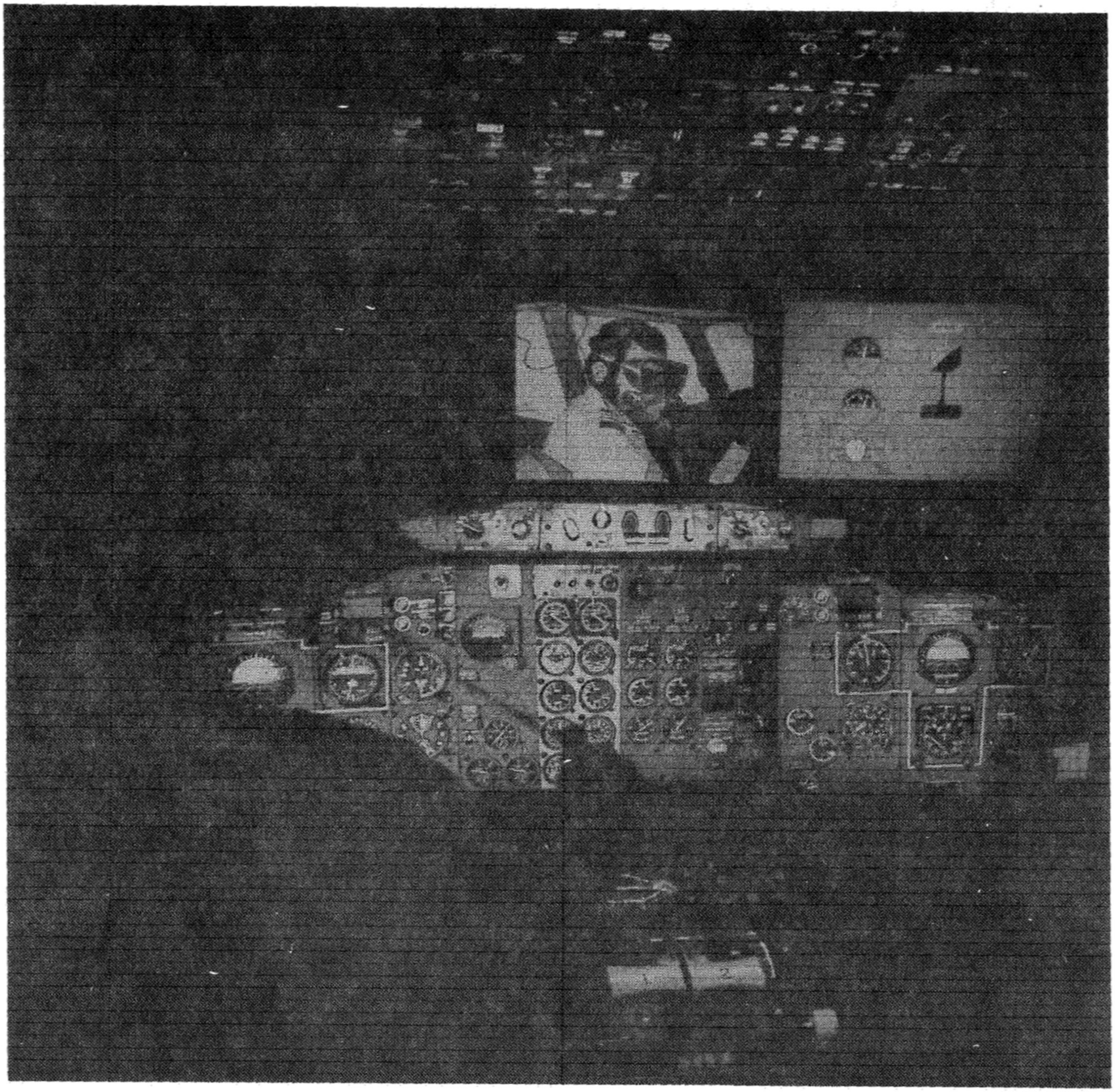

Figure 3.- A total learning environment for systems knowledge and procedural skill training which provides for an integrated instructional technology.

technologies available for training and how they can be integrated into a total training environment.

The two examples that I've just given you highlight the two guiding factors in training technology. First of all, provide only the physical fidelity or realism necessary to meet the training objective and, two, provide the instructional support to insure the most effective use of the training device.

Up to this point I have described devices which have been effective in training for today's aircraft technology. I would like to take the remaining time to discuss some training problems that will probably arise in your operations in the not too distant future.

I'm sure that all of you are aware of the fact that aircraft cockpit instrumentation and control systems are undergoing a gradual but inevitable change. Microprocessor technology and high resolution graphic displays are being introduced into the cockpit with increasing frequency. The following series of slides illustrates this trend.

(Figures unavailable for publication)

This is an inside shot of a Boeing 747 conventional cockpit. And this is a Boeing 767. We are seeing the initial introduction of CRT displays. The next is the FA-18 Navy fighter and you'll see how the explosion in microprocessor technology has found its way into the cockpit. There are a variety of multifunction integrated displays on this system as well as the head-up display, and the sidearm control fly-by-wire system.

And last, NASA's own advanced cockpit here at Ames Research Center which was designed by Lockheed Georgia. And you see some of the things I'm addressing here that are inevitably going to find their way into the cockpit of the future. You see a whole variety of multifunction flat panel displays in the cockpit, a lot of keyboard entry, head-up displays mounted on the wind screen and the sidearm controller. The amount and variety of information that a pilot will have access to in the cockpit will increase rapidly in the next decade. There is no doubt about that.

Multifunction integrated displays will replace conventional flight and engine instrumentation. They will also be capable of displaying fuel, electrical and hydraulic system status, digital images of charts and maps and even the relative position of other aircraft operating in the vicinity. Only a small number of CRT or flat panel displays will be provided. Each will serve many functions.

For the seasoned pilot accustomed to scanning conventional instrument displays, extracting the right information when it is needed from these systems may require extensive training. Some of these systems have a dozen or more display modes, each mode having several different display configurations.

Furthermore, these systems will be providing a quantity of new information and symbology which older conventional aircraft do not provide. Interpreting and using that new information effectively creates a unique training problem. Those that make extensive use of this technology now, the military service, are already discovering that training pilots to use this technology is not a simple matter. Substantial simulator and aircraft training may be required to familiarize pilots with operations of these new systems.

Since the cost of such training is obviously very high, some innovative techniques are being tried. One way of training pilots to operate this new cockpit technology, specifically multifunction displays, is through the use of special function trainers.

The trainers are composed of small desktop computers coupled with high resolution color graphic displays. The displays can provide the same information available in the aircraft with the same level of detail. The pilot can operate the system through light pens, keyboards or touch sensitive membranes.

(Figure 4 here)

Two examples of the many systems that are currently being developed are shown on the following slides. This is a special function trainer that is designed to train for the head-up display, the weapon and stores control panels for the new Northrop F-20 fighter.

(Figure 5 here)

The next slide shows another example of the utility of special function trainers for use in training CDU operations in 757/767 aircraft. They are easily transported to wherever the aircraft is based. They are highly flexible since only software changes are required to create new display system. Most of all, they are effective in supplying the training needed.

I began this talk by noting some fundamental differences between training technology and simulation technology, and I provided some examples of low-cost training technology that have been effective in lessening the cost of air crew training. I also showed how the same

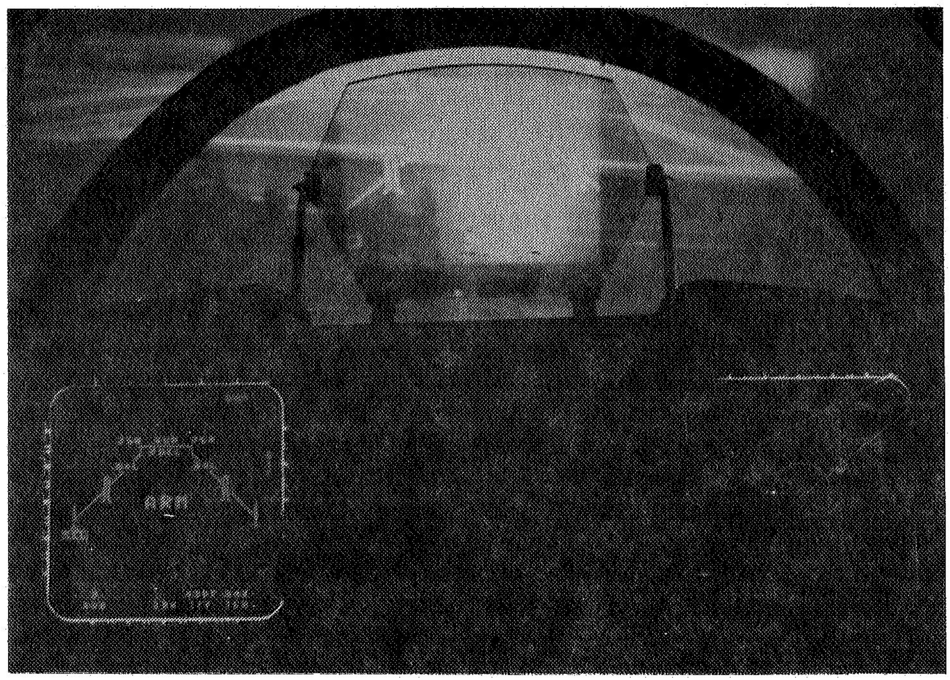


Figure 4.- Head-up-display trainer for Northrup F-20 fighter.

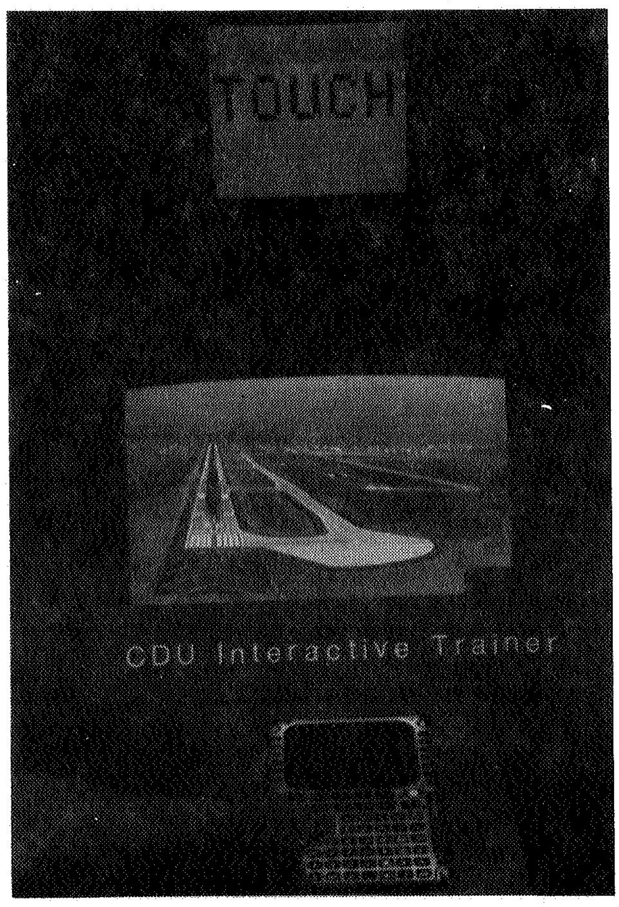


Figure 5.- CDU interactive trainer for 757/767 aircraft.

computer technology that is entering the aircraft cockpit can play a major role in training pilots in the future.

It is important to keep in mind, however, that technological innovations should not dictate what kind or training program you develop. Define the training objective first and then decide on what training system is needed.

DISCUSSION

DR. LAUBER: Thank you, Al. A very interesting discussion. Again, I have a couple of questions.

One question that I have has to do with the technology issue. By incorporating microprocessors in the cockpit of the new generation of aircraft, it seems that you are also providing the potential for the inclusion of training modes as well as operational modes in these devices.

Do you know what, if anything, has been done with some of the military systems that you talked about? Do they include training modes in the onboard avionic systems of some of the advanced aircraft?

DR. LEE: Let me state a kind of philosophy about these new systems that I think that most of you probably share. It's been my experience in dealing with military pilots that the folks in the software department have gone a bit beyond the call of duty in designing some of these systems. I found that many pilots spend a great deal of time trying to figure out just exactly what this thing is supposed to do. We have a very powerful technology here, but it doesn't seem that either in the design or in the conceptual stage we've really considered what the pilot has to do to deal with that information.

So to answer your questions, there is no specific training mode included. As far as I can tell at this state, it is all a training mode. The pilots will frequently go through as many of these displays modes as they can in the shortest time possible and try to figure out what they are looking for. So right now I think the technology that is being introduced into the cockpit has not dealt with the human factors issue very well at all.

MR. BEUTLER: I'm Grant Beutler from Seville Training Systems. Would you talk just a bit about the self teaching capability of that computer that was behind that one kind of device, what kind of instructions were given and what the results have been with it?

DR. LEE: Which device?

MR. BEUTLER: The one that had a terminal on the left side there.

DR. LEE: Okay, the Navy's training system. Basically, the CRT is manually driven, so it will provide the student with the manual select maneuvers or procedures that they would like to practice. And the student will simply select one, and following that the system will generate in text form what switches and dials have to be repositioned to set up for that particular maneuver. Once the start button is "pushed" it goes to that sequence.

Now, that particular system is designed only to provide -- and this goes back to Paul Caro's discussion -- some of the onset cues for malfunctions that occur. It does not give a progressive degradation of malfunctions that would occur if the student did nothing.

So the key, I think, in that system and in systems like it is to provide the kind of onset information that you'd like the pilot to condition his response to at the outset rather than trying to turn all the possible degradations that the system could go through before the malfunction was corrected.

MR. FELL: The question would be: You showed a couple of trainers that were Navy trainers. One had, I believe, a heads up display, part task trainer, and another weather radar. My question is: Are those separate trainers and are they teaching just part task training for each individual system in the Navy? And if so, is the assumption that when they are thrown into the aircraft or full motion simulator that they are going to be able to assimilate all that knowledge that they have gained into one overall full mission type trainer? Or how do they assimilate all that knowledge into one final piece of information to analyze the pilot's abilities?

DR. LEE: At this point I think the technology is so far ahead of our concept of trained people, that is not a particularly easy question to answer. What has happened, I think, is that systems have been retrofitted in some cases, in some aircraft cockpits, and in other cases they have been put in without too much concern with integrating their information into other systems that are already available. So I think what's been done has been often a very quick fix to a problem that I think is growing very rapidly, particularly in the military services, so that these systems are in fact just part task, and the finishing touches, so to speak, the integration of skill occurs later on more advanced systems or in the aircraft itself.

DR. LAUBER: We have one more in the back of the room.

MR. DALY: Paul Daly, Embry-Riddle University. I'm a little confused as to what lesson you're trying to teach me. I got the impression that you were providing part task trainers like the one for the SH3H, and yet in answering questions you seem to be presenting the idea that maybe part task training is not a feasible approach. What exactly are you driving at? First of all you downgraded them into the part task training and then you cast them into a system statement or something.

DR. LEE: I'm not sure if I understand your question. But my intention is not to downgrade part task trainers or the concept. I simply provided those systems as a demonstration of how in some cases you can eliminate some physical realism and not suffer an impact on training effectiveness as a result.

MR. DALY: Well, I would agree. What are you saying is you can use part task trainers effectively and not only training effectively but cost effectively?

DR. LEE: Yes.

DR. LAUBER: Okay. Thank you again, Al.

Again, I hate to cut off discussion, but we will have plenty of opportunity to come back either later today or tomorrow or during the individual working group meetings to address specific questions to Al or the others who are speaking here.

We are going to switch themes at this point. What we've been talking about so far this morning is training technology, simulation technology, training aids and devices. And most of that discussion has been oriented toward the technical skills aspect of training.

All of us in this room are aware that training the technical skills required to fly an airplane is only part of the problem. We've come to recognize that there are far more complex skills involved in operating a modern airplane including what we call cockpit resource management and related kinds of issues; things having to do with leadership and the development of command authority, communication on the flight deck and similar things that several of us here at NASA have an abiding interest in.

So the next several presentations are actually going to deal with various approaches to this kind of training taken by several airlines to again get you thinking about some of the issues and some of the approaches that have been taken, the relationship between the weather display and the outside or external scene from the cockpit. And the keyboard allows, say, putting in different course changes and what not. So it's really a rather artifactual view, but it takes the point that both Paul and I make that we're really trying to train a particular kind of cognitive skill here, and it's not always necessary to have things in the exact configuration they are on the aircraft.

CAPT. SIFFORD: It's a stand-alone system; is that correct?

DR. LEE: Yes.

DR. LAUBER: Two more questions. Go ahead. Back here.

A VOICE: You mentioned a study that showed the benefits of low cost simulation versus high cost simulation, but you didn't mention what that study was. I'd be interested in knowing what the study was and what type of pilot groups were involved in that study.

DR. LEE: I can give you a copy of the article, but, as I recall, they were initial qualifying trainees into the -- two aircraft were essentially tested. The SH3H helicopter was compared to a fixed base operational flight trainer with a visual system but no motion. And the comparison was the rate of acquisition of skill on both systems and the performance in the aircraft at the end of it. Basically the differences are not statistically significant. I think there is probably a half an hour difference.

A VOICE: With regard to the high cost simulator, could you tell me would you have any knowledge of what criteria were used to evaluate that device and the low cost device? Were there any hardcore criteria that either one was evaluated against?

DR. LEE: You mean as far as pilot performance is concerned?

A VOICE: As far as the device itself in matching aircraft performance.

DR. LEE: No, I don't think there was that kind of systematic comparison of every possible specification. What I think the Navy did was say what can we get away with here, what can we do with the least, and went from that point. I don't think there was any kind of broad technological framework to this. I think it was a trial and error process that they went through.

MR. FELL: Based on your knowledge and experience, would you say that that perhaps is a good learning approach, or based on their experience and your experience in observing them, has that worked? Or do you think the Navy or any armed services or any commercial carriers should go more toward analyzing the pilot's ability in a full mission simulator prior to sending him to the line? Or do you think the part task trainers are adequate in assuring the pilot's capabilities?

DR. LEE: I think that some integration is necessary along the way. These systems have become so dominant in the cockpit that it just takes so much time in simulation or in the aircraft that you are really forced by circumstances to take a part task approach.

Now, from what I can tell, and there is some data to support this, the pilots do have a much easier time of integrating this new display technology, this new information, into all of the other information they have in the cockpit provided they are given some part task training at the outset. If not, not only their responses to a particular system like the heads-up display degrades but sometimes it overflows into other behavior as well.

CAPT. SIFFORD: Jim Sifford with Piedmont. In the trainer that you showed us, it appeared that that radar screen was above that of a windshield of a simulator, or was that in a real airplane? That's the first question. Second, approximate cost? And third, this is for teaching peripheral systems for the airplane such as performance management system in a generic sense as well as heads up display or automatic recording systems such as a peripheral system in general. Is this the intent of this?

DR. LEE: Of the weather radar system?

CAPT.SIFFORD: Of the trainer as you had it depicted there.

DR. LEE: That is a part task system that's fixed base, and I don't have the precise figures on it offhand. It's still under a prototype contract development. I'm not sure exactly if I have your question right, but as far as the weather radar is concerned, that's an integrated part of the system.

CAPT. SIFFORD: On your display on the slide, it appeared it was mounted over a windshield or something of that type.

DR. LEE: The reason for that was that in this particular system there is some training going on that shows with the idea in mind when we get into our discussions with the individual working groups tomorrow, you will make use of this material to come up with sound, substantive recommendations that can be applied to your own specific operations.

The next two speakers are from USAir. Captain Stan Fickes is a flight operations manager on the 737 airplane. He was employed by USAir when it was still Allegheny. And in 1967 was named check airman and flight instructor and has approximately 16,000 flight hours. Stan was the individual -- we've worked with Stan before -- who was responsible for the introduction of cockpit resource management at USAir and is also concerned with the introduction and new aircraft procurement programs and the development of training programs for those new aircraft.

Dr. Bob Sellards is a PhD. His degree is in clinical psychology from the University of Pittsburgh. He teaches at the University of Pittsburgh Medical School, the University of West Virginia and Indiana University medical schools and also works as a consultant to several professional football teams. I'm going to be interested to see if Bob really ties that into his presentation this morning.

Bob flew medical evacuation helicopters in Vietnam, and has been working with pilots since Vietnam, with USAir for the past four years looking at various human factors issues including, he mentions, the issue of subtle pilot incapacitation and how to deal with that in training programs and the relationship of that to incidents and accidents.

So with that, I'd like to introduce the two gentlemen from USAir.