CONSERVATION OF PEOPLE, PLANES, AND PETROLEUM THROUGH OPTIMIZED HELICOPTER SIMULATION

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The Variable Cockpit Training System in use at the U.S. Coast Guard Aviation Training Center in Mobile, Alabama represents a drastic departure from traditional military pilot training. Through the use of a highly sophisticated flight simulator and several advanced training techinques the Coast Guard has realized dramatic savings in both training time and training costs. In addition, thousands of aircraft hours previously used in training have been released for use in other Coast Guard missions. Some of the new techniques were used in a pure aircraft training program prior to the delivery of the simulator. This allowed separate analysis of savings derived from certain facets of the program.

BACKGROUND

In 1973, the Coast Guard began using a helicopter training system incorporating a sophisticated simulation facility and many advanced training concepts never before implemented in an operational military flight training program. Three types of training are provided at the Aviation Training Center at Mobile, Alabama. Each year proficiency training is provided for all Coast Guard helicopter pilots in the HH-3F or HH-52A simulator to renew their instrument rating and provide realistic emergency procedures review never before available. This entire course, including the instrument checkride, is given in the simulator. Coast Guard pilots with rotary wing experience who are to be trained in the specific helicopter go through the Transition course. This involves training in the actual aircraft as well as the simulator. The Qualification course prepares fixed wing pilots for their rotary wing rating in the HH-52A. This also involves both aircraft and simulator training. We will discuss our first four years experience with this system, with emphasis on design features of both the simulator and the training program.

Before we discuss our new system, we will review traditional military pilot training to show the frame of reference from which the Coast Guard approached this new venture.

Traditional Subject Matter Emphasis

Prior to July 1972 all Coast Guard helicopter pilots were trained using the conventional method of training, i.e., learn aircraft systems in great detail through an instructor who stood up and lectured on the material. Flying the helicopter was not begun until the entire lecture series was completed. This was true of undergraduate pilot training with the Navy as well as transition or qualification training which was conducted by the Coast Guard.

Traditional Instructor Selection

As anyone who has attempted to do a research project in a routine pilot training program will tell you, the greatest source of variance in the way students are trained is the instructor pilot. To partially counteract this, standardized briefings are devised for each maneuver so the student will not be penalized for having an instructor who can't communicate his thoughts as well as another. In many cases instructors are chosen not for their ability, but for their availibility. Frequently graduating students are chosen to be flight instructors. Students usually get their choice of assignments according to their class standing. Priorities are usually arranged similar to this; fighters, bombers, transports, helicopters, desk jobs, and finally (gulp) instructor pilots.

Traditional Flight Syllabus

In order to ensure adequate coverage of all pilot skills, a strict syllabus was devised which instructors were expected to follow as accurately as possible. This thorough outline of how training time was to be spent was developed partially in response to a requirement for each class to finish on a preset date. Training commands were required to turn out a given number of pilots at given intervals. In order to comply, they had to have a pretty accurate picture of such things as the rate of attrition, weather delays, and aircraft availability. From the command point of view, following a rigid syllabus reduced the variability due to individual learning rates.

It is important to note that the Coast Guard pilots who worked in developing our present training program were products of traditional military training programs. It was at times difficult for them to override their concepts of what a military training program should be like.

The first break with tradition came in choosing the officers to serve as Coast Guard instructors. When the Training Division was first established in 1965, a decision was made to select instructors from operational pilots who first, wanted to be instructors, and second, were known to have the basic skills and personality to be good instructors. By the time this new training system was conceived there was on hand a group of highly motivated, highly respected instructors.

Still, there was a reluctance on the part of the instructors to develop such a radically different program as was envisioned. Their arguments can be summarized in two categories: First, they noted the present system had been successful for years and saw no reason to change; and second, in most cases those who had experience with simulators felt it had been a bad experience with no real training value.

DEVELOPMENT

In 1969, the Commandant requested a study of Coast Guard aviator training requirements to determine whether training costs could be reduced by using advanced training technology. This study, conducted by HumRRO, included a task analysis of operational pilots in each Coast Guard airplane. (Hall et al., 1969) It was determined that a revised training program taking advantage of new concepts and technology could reduce training costs considerably and increase overall training effectiveness. (Caro et al., 1969) The decision was made to develop a Variable Cockpit Training System (VCTS) for both Coast Guard helicopters.

From its inception in 1969, the VCTS was thought of as a flight training system which had a sophisticated simulator as an integral part, rather than as a simulator which might be squeezed into an existing training program. Design features of the simulator were evaluated on the basis of training value per dollar. As a result, we have no visual system which may have saved no more than two hours per student given the state of the art at that time. Six degrees of motion, on the other hand, were considered indispensable because of the cues provided for many of the malfunctions.

Primary contracts were eventually let to Reflectone, Inc. to build the simulator itself, and to HumRRO for assistance in developing the training program. An additional subcontract was let to NAVTRAEQUIPCEN for technical expertise in developing the specs for the simulator.

Training Program Features

Flight instructors were actively involved in developing the training program they were eventually going to use. Three instructors from each aircraft were given primary responsibility for creating the new training program with guidelines and assistance from HumRRO personnel. From time to time, other instructors were consulted regarding their area of expertise. Each of the three instructors was assigned to the Reflectone factory to assist in testing and acceptance of the new simulator for about a month at a time. The other two worked on writing the course material. This rotation was devised to provide them with a total picture for the new program. This also reduced the problem of the acceptance pilot adjusting to the simulator.

Several new training concepts served as focal points for the development of the new training system. As might be imagined, many heated discussions took place before implementation of such a radical departure from traditional flight training. In discussing each of these concepts, we will summarize some of the problems envisioned by the instructors and then report on their subsequent experience.

How to Operate the System

It was determined that the training program should focus on training objectives that can be evaluated by observing student behavior. These objectives should be related to tasks that a pilot might be expected to do in the operational environment. The student should know how to operate the aircraft systems in all normal and emergency conditions. He would not need to know all components of each system. If he can't control it from the cockpit, he doesn't need to know about it. The old school flight instructors were a little less than enthusiastic about this idea. Many examples were cited where a pilot had saved his "bacon" by knowing how to jury-rig an immediate correction for a system problem based on his thorough knowledge of the system. This is the most valid argument against the systems approach to training, and it must be dealt with. The answer, of course, is to ensure that all conceivable ways to operate a system from the cockpit are covered for all conceivable malfunctions.

In retrospect, this concept has been a great time saver in all courses. Training objectives defined in this way have proved successful as reflected in follow-up critiques from the operational units.

Proficiency Based Advancement

As soon as a student could perform a particular operation at an acceptable level he should be allowed to move on to the next level of difficulty. This is imperative when setting objectives in terms of expected behavior rather than material to be covered. When the objective has been met the lesson is complete.

It has been documented that acceptable performance to one instructor may not be acceptable to another. (Koonce 1972, and others) Pinning down the acceptable performance criteria for each maneuver required a lot of discussion. These ranged from very detailed to very brief. The general consensus of the instructors was that recording great amounts of detail was neither required nor desired during the flight. A form was finally adopted which dealt in broad maneuver categories requiring only a mark to show whether the attempt was "Satisfactory" or merely a "practice" trial. Additional detail could be added after the flight in space provided. The guidelines for satisfactory performance are still primarily subjective, however, they are validated as instructors rotate students during the latter phases of training.

Training Managers

Instructors were given the role of managing the conduct of each course they taught. One instructor was to take his students through the entire training program modifying it as necessary to ensure that his students met the end of course objectives. He would be responsible for all phases of training from study assignments and systems information, to the cockpit procedures training, the simulator, and into the aircraft. The academic phase was integrated into the simulator and flight phases. In the later operational phases the students would fly with other instructors to validate initial training and provide feedback to the principle instructors.

There was a general uneasiness among the new "training managers" who felt the need for the more comfortable guidelines they had had with the strict syllabus approach. They were eventually made comfortable with a list of maneuvers which must be accomplished satisfactorily before moving on to the next phase. Material previously presented in the first six lessons was collasped into "Phase One, Basic Land" with no time divisions or suggestions for how to use the lesson time.

Because the concept of Instructor Manager was new, it was difficult to provide the instructors with detailed descriptions of what steps to follow in setting up an outline of instruction. At first, great care had to be taken that each instructor did not set up his own mini syllabus, but rather used a proficiency based method of instruction.

As instructor managers gained experience they became more flexible in taking advantage of their freedom. New instructors who have come aboard after the first year are more receptive to this idea. Many of them went through this training system in their initial transition, and again when they went through the instructor course. As evidence that instructors are using their own judgement as to the time required in each phase, the standard deviation on total aircraft time in the HH-52A Transition Course has increased from 2.9 hours prior to VCTS to 7.2 hours in 1976.

New Training Program used without Simulator

As work on the training program and material progressed ahead of the hardware delivery, it was possible to experiment with some of these concepts in the all-aircraft HH-52A qualification course. Table 1 shows a comparison of times in the Qualification course, prior to implementation of the systems approach, with times using the new procedures, but without the simulator. Clearly, some of the savings attributed to the new training program are achievable without the simulator. No degradation of student terminal performance was noted by the admittedly skeptical check pilots, or subsequently by the units to which they were assigned.

TABLE 1. SAVINGS IN FLIGHT TIME USING ADVANCED TRAINING CONCEPTS WITHOUT THE SIMULATOR.

HH-52A QUALIFICATION COURSE	Mean Aircraft Time	SD
OLD SYSTEM	77.3	3.8
NEW SYSTEM	67.7	3.6
SAVINGS	9.6	

SIMULATOR FEATURES

The VCTS simulator complex consists of two highly sophisticated flight simulators - one each for the HH-52A and the HH-3F helicopter now in service. The simulators were built by Reflectone, Incoporated using a single Datacraft 6024/3 computer with a high-speed disk operating system. Each cockpit is installed on a six post synergistic motion system providing six degrees of freedom. Training time lost to maintenance problems remains below one percent.

Advanced training capabilities include performance playback, automated demonstrations of selected maneuvers, automated performance scoring and in-cockpit control of all training and environmental conditions. The instructor rides behind the students in position to both monitor their performance and operate the simulator controls. Two students receive training as a flight crew, with one acting as copilot. They must react to various malfunctions as a team without reliance on a safety pilot.

We will discuss each of these features as to their actual usefulness.

Performance Playback

The performance playback feature was intended to be used in debriefing students after a maneuver or malfunction. Although the capability exists to playback from one to five minutes, rarely is anymore than one minute used. Instructors find it very useful especially in high workload or stressful situations to play back the last minute of the event. We would like to have the capability to replay less than a minute as most such cases are of very short duration.

Automated Demonstration

Manuevers can be stored as performed by experts for demonstration. We have recorded many of the flight training maneuvers, but find little use for this feature. It would be of more value in primary training than at the advanced level undertaken here. Instructors feel that training is more effective if the student attempts the maneuver himself. Students at this level have little trouble visualizing a new maneuver from a verbal description.

Automated Performance Scoring

Subroutines within the simulator program allow for recording of frequency and time out of tolerance for each of twelve aircraft parameters when either the "exercise" or "checkride" mode is selected. The checkride module allows data to be stored permanently for statistical comparison. This data bank is now large enough to react to major changes in the training system.

We have previously reported mild correlations between instructors subjective grades and the computer scores (Povenmire and Ballantyne, 1976) and a highly significant differentiation between computer scores of students and those of instructors on the same checkride (Povenmire, 1974). It is obvious to us at this point that automated scoring may provide useful data regarding one phase of pilot performance - namely, accuracy of tracking. However, it is impossible to automatically measure all factors that indicate pilot performance. Many judgemental and rational processes are much more important than how well he maneuvers the aircraft.

Instructor in the Cockpit

We have realized all of the anticipated benefits and none of the anticipated disadvantages of having the instructor ride along in the moving cockpit. It was predicted that he might have serious orientation problems due to the washout features of the motion system which presents only onset cues and then returns to a near level attitude regardless of the simulated attitude. However, because of their high level of flight experience, instructors automatically look to the cockpit instruments and justify themselves to simulated pitch and bank information rather than look out the back window to find real attitude.

With all simulator controls at the instructor's console there is no need to have an additional operator at a remote site, thereby reducing the manpower requirement. When both simulators are operating there are two students and one instructor in each cockpit. There is also a technician on call in case of a system malfunction, but he is free to do other projects.

The perfect instructor, according to conversation with one well-known aviation psychologist would be both mute and quadruplegic. (Hagin 1972) We come close to achieving his desired conceptual result with healthy instructors. The instructor does not interact with the students in the context of the flight. If students tend to rely on him he overtly discourages them. If asked for advice he says something like, "I don't know sir I'm just a crewman." He is out of the line of vision for the students so they are forced to interact as a crew and troubleshoot between themselves. The instructor will intervene and freeze the simulator when the students either use an inefficient strategy in troubleshooting or become disoriented in an instrument maneuver. He then discusses the operation while the cockpit is frozen, or plays back their performance to show where they went wrong. His physical presence in the cockpit is very unobtrusive, but very essential in his role as a performance evaluator and prescriber.

ONGOING DEVELOPMENT

After three years of operation with the "new" training system shifts of personnel in leadership positions resulted in a questioning analysis of the program as it existed. Subsequently, two major areas were identified for critical analysis:

1. What is the training program accomplishing?

2. Is the training program responsive to the needs of operational Coast Guard units?

Program Evaluation

For the first three years training program accomplishment was measured in three separate ways - 1) Student critiques; 2) critiques completed by graduates' Commanding Officers and 3) automated performance scoring on an instrument checkride in the simulator. The two critiques were subjective in nature while the latter gave us detailed data on time in seconds and frequency that the pilot exceeded preset flight parameter limits. The numerical data clearly demonstrated that the performance of Coast Guard pilots on the instrument checkrides was improving year by year. (Povenmire and Ballantyne, 1976)

However, since the checkrides were administered only at the end of a course it was unclear as to whether the improvement was in the pilot or in the training programs. The very real possibility of an undesirable tendency for the instructors to teach the checkride existed. The data gathered did not provide any confirmable information on the pilot proficiency levels or tendencies in the service. It could be assumed that the lowering of checkride scores showed an increase in servicewide pilot proficiency, but other explanations were also viable. The student and Commanding Officer follow-up written critiques continued to indicate basic satisfaction with the level of training received. It was apparent that we were doing a reasonably good job of training while we had the pilot captive in Mobile but we weren't satisfied that we were able to evaluate the overall pilot training program of the Coast Guard. Accordingly, 1 January 1976 the Proficiency Course was revised so that the scored instrument checkride was administered as the first event.

This slight change designed specifically to provide a measure of Coast Guard wide proficiency levels also provided several synergistic effects. The instructor was able to identify individual pilot weaknesses while simultaneously completing the check flight requirements for annual instrument rating renewal and adding to our numerical score data base. The multiple goal accomplishment at the start of the course also freed two scheduled training periods for additional emergency procedures training as well as permitting the students time to practice maneuvers that they personally wished to work on. The numerical data accumulated to date indicates that the overall level of pilot proficiency has in fact improved over the years the simulator has been in use (Povenmire and Ballantyne, 1976), and each training program was raising skill levels during the course of the pilot's stay in Mobile. Allowing the pilots time to practice the procedures they wish has restored their interest in the course and eliminated the anticipated boredom.

While we were convinced that we were improving the overall skill levels of our helicopter pilots, the major goal of any training program is providing an end product that the user desires. Analysis of Transition and Qualification student critiques and surveys of air station Commanding Officers indicated that graduates of our Transition and Qualification courses were not performing typical copilot duties as well as desired. Subsequent review of our training program revealed that although the students receive many hours in the simulator as copilots, the real world of communications and search planning are not well simulated.

Program Changes

A slight shift of training emphasis in the simulator and addition of a practice search mission in the aircraft provided a quantum increase in the level of the graduates copilot skills with no increase in the overall course length. The shift also permitted the elimination of a two week navigation review course that Coast Guard helicopter pilots were attending at NAS Pensacola as part of their undergraduate pilot training. The success of a slight change in course content in meeting operational requirements illustrates the need for constant review of training program goals.

We also formalized a program to monitor reports of aircraft equipment failures submitted from the field units. As new problems would arise we would add them to our list of simulated malfunctions. This continuous updating of the training to reflect operating experience has added greatly to student pilot enthusiasm and acceptance. Our experience has definitely shown that advanced flight simulators will be most effective if the end product of the training program is what the user desires. Effort expended to keep simulator training current and relevant throughout the life of the training program is as important as effort spent in the original design of the simulator.

As a result of the new policy providing no proficiency flying for pilots assigned to non-flying billets, such as those at Coast Guard Headquarters, a new course was developed to requalify these people when they return to operational flying. This course has no previous counterpart and has not been included in the analysis below.

SAVINGS IN TIME

As we have shown above, some savings attributed to advanced training concepts used without the simulator were demonstrated in the HH-52A Qualification Course. Additional savings in excess of 30 hours per student were realized in this course when the entire training system was implemented.

In the HH-52A Transition Course additional training requirements were identified which required additional training time. Unfortunately, we cannot identify the exact amount of time required for each student to meet these additional objectives; a conservative guess based on estimated flight time required to teach each new skill as part of another flight rather than as a separate flight solely for that purpose might easily account for between five and seven hours. On the other hand, after training students to react properly to an engine failure in the simulator we had to add a maneuver to the simulator training program called "practice autorotations." This was to preclude a student from shutting down the engine in a practice situation in the aircraft and to assure that the engine was brought back on the line prior to the critical point. Although the total cockpit training time increased over the old Transition Course, we have reduced the calendar time requirement from six weeks in the previous course to four weeks. The HH-3F Transition Course has actually produced an average savings in excess of seven hours over the old course.

Table 2 summarizes these savings for the three courses where aircraft are still used. In addition to these savings, one HH-52A aircraft was removed from the Aviation Training Center allotment when the VCTS was implemented.

TABLE 2. TIME SAVINGS PER STUDENT FOR EACH COURSE

	HH52A QUALIFICATION COURSE			HH52A TRANSITION COURSE			HH3F TRANSITION COURSE		
	FLIGHT	VCTS	WEEKS	FLIGHT	VCTS	WEEKS	FLIGHT	VCTS	WEEKS
OLD METHOD	77.3		9	*35.8		6	34.9		6
NEW METHOD NO SIM.	67.8		7						
COMPLETE NEW SYSTEM	36.6	23.9	5	30.8	16.4	4	27.3	30.8	6
TIME SAVED	40.7		4	5.0		2	7.6		0
STUDENTS PER YEAR	18			30			32		
TOTAL ANNUAL SAVINGS	732.6			150.0			243.2		

*Adjusted time reflects approximately five hours of additional training which was not included in previous course but is presently being given.

Additional savings were realized with the implementation of the Proficiency Course. This was an entirely new course intended to centralize and intensify the instrument and emergency procedures training that was previously being done at each unit. No hard figures are available to indicate how much training was actually replaced. As a matter of policy the annual training requirements for each aviator was reduced by 12 hours. This releases approximately 6,000 hours a year to the Coast Guard for use in other missions.

SAVINGS IN DOLLARS

In determining the cost per hour for running the simulator, all costs associated with the VCTS were itemized and divided by the actual number of training hours utilized. Costs included the following: field service maintenance, student travel for all courses, student per diem allowance, salaries of five civilians and one officer added when VCTS became operational, and, last <u>and</u> least, utilities. These costs have increased over the past three years along with everything else. However, utilization has increased proportionately. Our costs per student hour have remained between 48 and 60 dollars.

The total cost for the first four quarters of fiscal 1976 was $404,744. During the same period 7,845.8 student hours of training were conducted yielding a cost per student hour of $51.59.

Using operating costs established for federal budget determination, actual aircraft hours saved in the Qualification and Transition courses, and the aircraft hours released from the training requirements by the Proficiency to other Coast Guard missions we have been able to demonstrate savings in excess of $2 million during 1976.

SAVING OF LIVES

On several occasions our simulators have been used to assist in accident investigation. The accident review board brought both pilots to Mobile after an HH-3F had become uncontrollable. By simulating the intermittent failure of the suspected components the pilots "confirmed that the simulator maneuvers were identical to the aircraft reactions the night of the accident." (Tydings, 1977) Although this malfunction had been simulated in the Proficiency Course, it had not been shown in the intermittant mode. This has since been added to our list of required malfunctions in the Proficiency Course.

On another occasion, an accident review board attributed an HH-52A pilot's successful autorotation in an extremely critical realm of flight to "low altitude techniques demonstrated and practiced during the annual training received in the Variable Cockpit Training Simulator (VCTS) at Mobile." (USCG, 1977).

Although documented only by a phone call, we have saved at least one aircraft. The pilot of an HH-3F called the Chief of the Training Division to express his gratitude after having virtually the same serious control malfunction which had caused the crash of the HH-3F discussed above. He said, in effect, that because he had seen it in the simulator he was able to recognize it immediately and switch to a redundent system. He continued to his destination through the clouds over the mountains near Kodiak, Alaska. Acquisition cost for one HH-3F is just slightly higher than the cost of the entire VCTS simulator complex.

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