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Proceedings of LSO Training R&D Seminar

R. Breaux, Ph.D.
Human Factors Laboratory

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PREFACE

The objective of the seminar was to provide a forum for senior fleet LSO's to review the results to date on project 7754 of the Naval Training Equipment Center. Project 7754 is a 6.2 R&D effort seeking to define requirements for a universal LSO waving training system. The technologies to be reviewed were development of Behavioral Objectives, Waving Decision Making Models, Performance Assessment Techniques, Basic System Design concepts, and Laboratory/Demonstration Training Systems.

The final efforts under this project will be development of models of critical pilot behavior and of instructor behavior. Pilot models will be used to generate specific example situations. These critical situations are expected to teach the LSO to recognize key factors leading to waving decisions. Instructor models will provide management of the various subsystems by managing the information within the training system and presenting it to the human instructor in such a way as to provide graceful man/machine interaction. Of particular interest will be cost effectiveness estimates from a review of accident reports during the model development effort.

R. BREAUX, Ph.D.
Scientific Officer

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The exploratory development program at the Naval Training Equipment Center concerned with developing design guidance for a universal landing signal officer (LSO) waving training system was reviewed in depth during this two day seminar. Each contract and in-house effort was discussed by the principal investigators themselves. The Office of Naval Research was also represented in the presentations, providing review of theoretical issues uncovered during the course of the project. Comments, suggestions, and recommendations

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were provided from Fleet LSO's during the presentation. The final session was used as a planning session to discuss the direction of follow-on efforts.

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INSTRUCTIONAL RESEARCH AND TRAINING SYSTEMS FOR LANDING SIGNAL OFFICERS

DR. HENRY M. HALFF
Office of Naval Research

The purpose of this presentation is to inform a rather diverse audience of the Office of Naval Research's (ONR) interest in this seminar and in the Naval Training Equipment Center's (NTEC) plans for Landing Signal Officer (LSO) training. The simple explanation for the seminar is that it struck Robert and myself as a promising way of exploring the applied aspects of ONR's research in perception and cognition. In the rest of this paper I will try to explain why we saw some potential in interfacing our two programs and why we chose this particular mechanism. I will begin with a few words on ONR's mission and relevant research, a topic on which I am fairly well informed. I will then say a good deal more about the application of ONR research to NTEC's LSO training program, but you should know that my knowledge of this program is small indeed as is my knowledge of the LSO's job itself. In fact, the sum total of my information comes from Logicon's design study on the subject (Hooks, Butler, Cullen & Petersen, 1978).

As I mentioned, I stand on firmer ground when speaking about ONR. To quote from our own description of the contract research and technology program (Office of Naval Research, 1978), ONR sponsors "long-range scientific research believed to offer potential for the advancement and improvement of naval operations." Let me comment on a couple of ambiguities in this statement. First, the term long-range is interpreted in our office as being in the neighborhood of five to fifteen years away from application. Hence, one of the questions which I should answer is how ONR became involved in the LSO training project, given any reasonable expectations about the pace of NTEC's development of the work. Another question about the statement is "Who does the believing in this research?" Officially this faith is distributed throughout ONR's official chain of command, but in fact the major share of the responsibility for our research rests in people like myself. A first look at ONR reveals something very much like a university, with departments organized around academic disciplines and professionals who are given considerable latitude in deciding what research should be done within these disciplines. Here, however, the resemblance to a university ends since we must be responsive to an entity called the future Navy, a fact not often appreciated by either the present Navy or by our contractors. We try to choose research areas which will 1) address the particular problems which this unseen organization will face, e.g., fewer and less-intelligent people and more complex equipment; 2) afford greatest leverage with our current limited resources; and 3) represent high quality basic research. To expand this description by one level, the departments in our "university", called divisions at ONR, include three very applied research areas, which I need not mention, and six basic-research areas: Physical Sciences, Mathematical and Information Sciences, Biological Sciences, Arctic and Earth Sciences, Material Sciences, and Psychological Sciences, the smallest but most important division. I claim this importance because the Navy now spends most of its money not on planes, ships, and weapons, but on people.

Within Psychological Sciences, we support several types of research relevant to this seminar. We are divided into three branches: Organizational Effectiveness, Engineering Psychology, and my branch, Personnel and Training. The Organizational Effectiveness Programs might make a contribution to the team aspects of LSO training, but since this is not the primary thrust of NTEC's project, Robert did not request the presence of their representatives here. Our Engineering Psychology Programs could have much to contribute to this work. Perhaps the most pressing need which they could address is for some guidance on the crucial display issues for LSO training devices, and Robert suggested that we include some contractors working in that area. But the bulk of contractors at this conference are representatives of the Personnel and Training Research Programs. For some time now, much of the research sponsored by these programs has been focused on the advanced use of computers in testing, education and training. Some of that work, on computerized adaptive testing, is not particularly relevant here except as a possible source of mathematical models for proficiency assessment within the system. The rest of our research, however, has a strong cognitive and information-processing orientation, and it is the most appropriate of that work which Robert and I chose to have represented here.

Some of our most relevant research seems, oddly enough, to be in the area of individual differences in information-processing ability. It happens to be important in this context because we have particularly looked at individual differences in heavily time-driven tasks. In the course of this work we have had the opportunity to explore many issues relevant to LSO training including automaticity, attentional flexibility, and time-sharing capacity.

Another part of our program, called cognitive processes, is concerned with the cognitive analysis of highly-advanced information-processing skills. Some of these skills consist of fairly slow problem-solving and analysis activities, but others require the accurate perceptions and fast reactions characteristic of the LSO's job.

Perhaps the most relevant part of our research for this seminar is that on Instructional Theory and Advanced Training Systems. This work is the most recent direction of our long-standing interest in education and training applications of what is now called cognitive science. Our earlier work in the field was addressed to automated tutors for educational environments, but over the past couple of years we have shifted the research to deal with procedural knowledge and training systems. As with Cognitive Processes, some of that work is directed to training problem-solving skills, but much is directed explicitly to the instructional foundations of training in devices such as those being developed here at NTEC. Maybe part of the answer to the future-Navy question lies here. For, as the Hooks et al. (1978) and Chatfield, Marshall and Gidcumb (1979) point out, these devices will take on more and more of the training burden in the Navy, and little is known about the proper use of even the training devices now available; current flight simulators, for example, are often used for little more than aircraft surrogates.

Hooks et al. also point out many of the important questions which we hope to address in our own research programs. What is the best way of representing proficiency and advances therein? Is it possible to create computational models of these representations? Can performance data from simulators be used to assess proficiency within such models? The many parameters of particular exercises need to be determined at each point in training as a function of the syllabus, proficiency assessments, and instructor input; is there a theory which can guide this process? Finally, there are questions concerning the use of special instructional features such as voice technology, playback, and predictive displays. All indications are that in today's operational training devices these features are little used and less understood.

Borrowing Lord Hillary's words, I might comment that this LSO training program offers itself as an opportunity to consider these issues simple "because it is there." But there are, in addition, several features of the program which make it an attractive scenario. For one thing, the training environment is limited in important ways. The task itself is limited in time to the few seconds required to get the aircraft on the deck or wave her off. Likewise, the standard response repertoire is limited to a finite, even small, number of voice commands and switch closures. Also, the training environment itself is limited to a configuration which resembles a psychological laboratory more than the LSO workspace onboard a carrier.

This point is related to a second important aspect of the device, namely, experimental control. I have often been chided by educational psychologists who claim to be working in the real world (i.e., classrooms) while I puttered away in my fancy computer-controlled laboratory, which allowed me to present an infinite variety of precisely timed stimuli and collect responses of individuals with equal precision. Thanks to Robert and those working with him, I have the last laugh, for that laboratory situation has now become the real-world instructional environment. The requirements of flexibility to meet training needs also happen to provide stimulus control for experimental needs. The response measurements required for a responsive, interactive training environment are precise enough also to provide hard scientific data. The potential of these devices for precise instructional research is tremendous, and if such research produces less than satisfactory results, we cannot complain of a lack of control over the instructional environment.

But perhaps the most important aspect of this LSO training project and related efforts is the relevance of certain psychological issues which are the focus of much investigation in ONR research programs. These issues start slightly behind the eyeball for, as I mentioned, one of the central questions in this work is the best way to design a two-dimensional display for the training of obviously three-dimensional perceptual skills. A related issue is that of perceptual learning and breadth of experience. There is some indication that part of an LSO's expertise is acquired by observing a wide variety of aircraft approaches in different situations. This suggests that part of the LSO's perceptual skills resemble the pattern vocabularies found in chess players (Chase and Simon, 1973), circuit designers (Egan and Schwartz, 1979), and other skilled individuals. Research on the structure of these vocabularies might find direct applications to this project.

I have mentioned the issue of automaticity as being relevant here. Hooks et al. give considerable attention to this issue, suggesting that there are some perceptual components of the task which demand large attentional resources in novices but become highly automated in experts. Laboratory techniques for investigating automaticity should be advanced enough to allow us to identify those task components and perhaps suggest opportunities for part-task training. The other and more interesting aspect of this issue is that of task integration, an aspect which Hooks et al. also discuss at some length. They point out that one can functionally divide the task into four parts. Two of these have to do with assessment of overall recovery conditions (e.g., weather) and are not relevant here. The other two are assessing the aircraft approach (Stage 1) and directing the pilot's actions (Stage 2). It is not known if this Stage-1, Stage-2 functional description is psychologically valid or if, in the expert, the perceptual, Stage-1, processes map directly to the action, Stage-2, processes. And, even if the two stages are functionally separate, they must proceed in parallel in real time, raising questions of interstage interactions, contingencies, and competition for attentional resources. I feel some obligation to cite the large body of current research relevant to this topic, but fortunately I can avoid this chore by referring you to Chatfield et al.'s (1979) thorough review of the subject.

Decision making is also mentioned in Hooks et al. as an important part of the LSO's job. He must be able to estimate the chances of a successful landing given the particular recovery conditions and the approach itself. This, combined with operational requirements at the time, result in a decision to allow a landing or wave the aircraft off. As Hooks et al. point out, the LSO must be able to trade safety for rate of landing, but clearly the tradeoff point is not set during the approach. I would assume that in most cases the LSO's assessment of recovery conditions and operational requirements serve to establish a context for his handling of the approach. This suggests that some attention to the structure of the context space could benefit the training of an LSO's decision-making skills. The ability to vary approach characteristics and contextual conditions independently in this training system (again note the importance of control) offers a prime opportunity for mapping this structure.

Two final issues which I will discuss are not mentioned in Hooks et al., but judging from our own work, they should be considered relevant here. One of these is the development of action skills which directly control the LSO's words and actions. Some of our recent research (Norman, 1979) indicates that we should be concerned about human errors or slips made in the course of highly automatized actions. The two response systems used by the LSO particularly invite these errors; these systems are the moderately complex key system used to operate the Fresnel Lense Optical Landing System and the extremely complex speech production system centered between the LSO's ears (perhaps a bit nearer the left ear). Many of these slips occur because of developing automaticity and the consequent squeezing of tolerances in the cognitive system. That we could use training techniques to standardize these tolerances is an exciting but not farfetched prospect.

The last issue which I find interesting in this context is best introduced by referring to LSO comments cited in Hooks et al. on "Qualities that separate the outstanding LSO," namely, "Overwhelming emphasis on ... ability to see problems early on, preferably, before they happen." The basis of this ability to plan and anticipate must have multiple sources. Some of it simply depends on the knowledge of how planes and pilots behave, that is, the same type of knowledge that allows for an accurate simulation of an approach, once the parameters are set. But if research in other areas of psychology and cognitive science (e.g., Schank & Abelson, 1977) is any indication, this knowledge is not sufficient; also involved are cognitive structures representing the situation which go beyond physical (and psychological) laws. The concept of a "call window" is probably one component of such a structure. Such structures might allow a skilled LSO to divide an approach into functional subparts, to detect and classify aberrant approaches, to limit searches for possible futures, etc. The cutting edge of our research program is the creation of methods for building explicit computational models of such cognitive structures in the hope that they can be of use in training systems such as this. These models provide much better ways of establishing proficiency through verbal explanation; they also provide a psychological basis for part-task training, for instructional sequencing, and for proficiency assessment. Again, I can refer you to Chatfield et al. (1979) for further speculations on this prospect.

Having finished the interesting part of my talk, I must now return to the question posed at its outset, "What is ONR's interest in this training system, especially considering the long-range nature of our interests?" Some of ONR's basic research is like baking a cake, which one puts in the oven and protects from all disturbances until done. However, the research represented here is more like cooking crepes; you know that the first few will not turn out so well, but unless you start nibbling at them, the later ones will be just as bad. Thus, this meeting is part of an ongoing interaction of ONR's basic research activities with the applied research community, and we need to ask about the immediate as well as the long-term goals of this interaction.

Turning to immediate benefits, ONR has been involved in computer-based training and instruction since the sixties and in fact may lay claim to the invention of that field. So it would surprise me if our collective program has nothing at all to say about this particular application. Since I know little about computer-based training and less about LSO's, I have no suggestions to make now, and I suspect that most of us are in a similar position. After the meeting, I hope that things will be different, and I expect that our contractors can make two sorts of immediate contributions. (Both of these ideas, by the way, have come from our contractors, not myself.) First, there is a good deal of practical information, lab lore, that never finds its way into technical reports, much less into the published literature. Such lab lore may include relatively simple items, such as solutions to problems of contact bounce and stutter in keyboards, as well as high level information on, say, the feasibility of natural language interfaces. We rarely publish reports on our failures, but information on what cannot be done is crucially important in the applied world. The second suggestion for immediate use of basic research is the use of existing theory to identify important problems, points, issues, etc. On this model we assume that instructional design is something of a craft so that tasks such as syllabus construction cannot be formulated top down from the results of basic research. What can be had from basic research are the types of results contained in Hooks et al. and Chatfield et al. For example, concurrent task situations can be identified so that performance assessment can include dual-task measurements. Aspects of proficient performance can be analyzed in terms of levels of cognitive control, etc. I hope that at this meeting and in the coming months we can start an interaction with the system developers to make this unwritten knowledge available and applicable to their task.

As you may have guessed from my previous remarks, there are considerable points at which further research could lead to enhanced use of this and similar systems, and provide important information on skill acquisition and training technology in general. Effort and time will be required to do a proper job on this research, and most of it, I imagine, will not be accomplished in time to influence the LSO training project itself. It is because we feel that the future Navy is going to rely heavily on these kinds of training systems that we are prepared to start research on today's problems in this area. We will invest whatever is appropriate (in the light of other priorities) to provide the basic research which supports the development of these sophisticated devices in general. (In this area, as in most, we do not solicit proposals. Rather, the ideas must come from the research community themselves, and therefore an unsolicited proposal is the most appropriate route.) I know of no other way of introducing the research community to the general issues connected with these systems than to educate them in the particulars of at least one example. You should, however, be aware that our interests are not primarily with this particular training system. Rather, they are concerned with instructional management for the roughly defined family of systems of which this is one good instance. Those who are interested will try to extract the general characteristics of the family, educate themselves about other instances, and, we hope, be able to provide useful research on their design and use.

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THE NAVY PLAN FOR LSO TRAINING
AND THE LSO PHASE ONE SCHOOL

LCDR W.K.GRUVER
LSO TRAINING MODEL MANAGER

SUMMARY

Establishment of the LSO Training Model Manager at LSO school has created a centralized control point for the management of all LSO matters. Personnel and equipment are two of the major areas of concern of the Model Manager. Knowing what billets exist, the people, their qualifications and rotation dates will now provide better management to both the Navy and the individual.

Evaluation of existing and future equipment is needed in order to provide the best means to safely control aircraft landings aboard aircraft carriers. To have a unified community and a central point of contact in the form of the Model Manager will aid both Navy commands and contractors.

Formal training given at LSO School has increased the expertise and knowledge level of all LSOs. Standardization is now consistent throughout the LSO community. Because of its single location, information received daily can be sent to all type command LSOs explaining the latest procedures.

BACKGROUND

Historically LSOs were trained on the job with very little, if any, formal training. Being an LSO was merely a collateral duty with no career potential. With the evolvement to our present day all-weather day/night carrier operations and the sophistication of today's aircraft, the role of the LSO has had to change. He has replaced his paddles with a pickle, the straight deck has changed to an angle deck, and the cut given a prop with the automatic carrier landing of a jet.

In 1974 LSO training was formalized into a single school located at NAS Pensacola, Florida. In order to be designated an LSO attendence at this school is required. Sixty hours of classroom lectures are given and trips are taken to observe field equipment and day/night carrier operations aboard ship. Actual LSO equipment is used as training aids and guest speakers are scheduled for each class.

In 1979 the Officer-in-Charge of LSO School was assigned as the Training Model Manager. It was recognized that all of the LSO billets had not been identified Navywide. Also there was no complete list of people and their qualifications. To overcome this situation a computer program was developed to monitor all LSOs. Their location, qualifications, and rotation dates are now being monitored by the Model Manager and this information is being sent to type command LSOs.

A formal career pattern has been established for LSOs. There is now a specific pattern to follow and each stage and designation has been defined. Studies show that LSOs have a higher selection rate to Commander than standard aviators.

Because of our peace time commitments, total flight time and arrested landings Navywide have greatly decreased. To offset this reduced exposure, an LSO simulator has been developed and installed at NAS Lemore and NAS Cecil. Studies are being conducted to show the actual effectiveness of these devices and the amount of time saved in training. We are striving to produce a better trained LSO in a shorter amount of time.

Other equipment such as the LSO and and the LSO workstation are being evaluated by different departments. To keep pace with our changing times will require continuous evaluation of equipment in current use and the development of new equipment to insure the safe and expeditious recovery of aircraft.

OBJECTIVES AND PLANS OF THE LSO TRAINING R&D PROGRAM

DR. R. BREAUX
Human Factors Laboratory
Naval Training Equipment Center

INTRODUCTION

The major objective of the LSO R&D program has been to reduce the dependence upon traditional on-the-job-training (OJT) for the LSO. The emphasis has not been to eliminate OJT, but to reduce the amount required. The two major design goals have been to maintain proficiency and teach younger LSO's their job. As an effort to teach, the R&D program has sought definition of behavioral objectives and development of a training syllabus. Systems have been explored which would allow the trainee to get the pickle sooner, because the kind of training that would be given would result in a trainee in which the controlling LSO has more confidence. The trainee would be responsible for his own training and would know exactly what it was he wants the LSO to teach him.

As an effort to maintain proficiency, the R&D program has explored just what it is an LSO can see. How large a deviation is dectectable by the LSO's eye? What field of view is required to provide sufficient information for control of the aircraft and for feedback on performance? What are the ways which LSO performance can be measured? Studies have been conducted in each of these areas, and the results will be presented in later papers.

Let's look at some specifics in the teaching efforts. The three major models of an LSO waving training system include waving itself, aircraft/pilot/environment, and the instructor. The first model, waving, must be able to provide decisions as to what call to issue given a particular situation. Thus, in a training system allowing a dynamic interaction between LSO and simulated pilot, the waving model "knows" the proper action to take at any point in time and serves as a basis of performance assessment. The second model, aircraft/pilot/environment, must be able to provide flight situations which can teach a concept to the LSO. Thus, as the trainee gains in skill level on basic decisions and simple situations, the aircraft/pilot/environment model is tapped to provide training situations graduated in complexity and amount of information processing required of the trainee. The third model, instructor, must be able to manage the training process and interact with the human instructor and trainee. Thus, the instructor model analyses performance, critiques performance, and provides objective recommendations to the human instructor in terms of the trainee's skill level. So the teaching system is a combination of subsystems integrated for the purpose of assisting the instructor LSO to analyze and interpret trainee behavior, technique, and skill, and to aid the instructor in developing the trainee via a structured series of example situations and key concepts.

Of course the teaching effort requires a visual system. The R&D effort has sought to determine requirements for field of view, resolution of image, detectable deviations and depiction of deviations. Studies will be reported in later papers which discuss field of view required by the LSO so he can gain insight in pilot performance. The LSO typically will mentally backtrack from the wire caught in order to grade the approach. What requirement does this add to the training system for an LSO? Also, the LSO looks at a few lights at night to gather his information. Deviations from optimal approach profile must be detected and action taken based on these lights. What type and size of deviations can the LSO perceive, and how consistently do LSO's respond to these deviations. Finally, systems must be constructed to adequately represent a visual scene in order that the LSO may learn his key decisions and concepts. What exists in the market place to meet the training requirements in a cost effective and training effective way?

FUTURE DIRECTIONS

There are still questions to be answered, as you might guess. These concern some very real issues which often determine whether a training effort will eventually be funded. What is the cost effectiveness of a universal LSO waving training system? Certainly the saving of a single fatality would pay for any amount of R&D, but hard numbers are required on most budget justification documents.

How long would it take to pay for a training system? Estimates are needed which show cost of current training, effectiveness of that training, and skills which would be improved given application of principles which have been learned from the R&D efforts. Certain skills must be selected which can be taught in a training system, then an estimate must be made of the cost to teach those skills vs. things remaining the way they are. This pay-off should be in hard numbers as much as possible.

Some current efforts are seeking to uncover these numbers. One seeks to build a laboratory system to teach waving decision making. The study will provide some training time estimates for teaching LSO concepts. It will be discussed in detail in a later paper. Another study seeks to evaluate the LSO Reverse Display, which will provide estimates of the effectiveness of that approach and technology. But future studies will be needed to provide pay-offs in hard numbers as to training savings and fleet readiness through the use of an LSO training system. These type studies can partially be done through analysis of existing accident reports, for example, but also will require that the Navy build a prototype system for field evaluation. Whether that prototype is built is dependent upon the Fleet itself. It will be built and tested only if the LSO community requests it.

THE LANDING SIGNAL OFFICER (LSO)
A HISTORICAL PERSPECTIVE

MR. GAIL J. BORDEN
Human Performance Research, Incorporated
Goleta, California

The purpose of my presentation is to provide a historical perspective of the LSO and his role in the carrier landing process. I will describe the job of the LSO, how changes in carrier operations have changed it over the years, problems encountered by the LSO community as a result of the changes, and some of the R&D studies conducted to resolve these problems.

The role of the LSO in the carrier landing process is to provide corrective assistance to the pilot during the final approach and landing phase. The key word is assistance. Primary responsibility for aircraft performance resides with the pilot.

The LSO has not always had this secondary role. Prior to the mid-1950s, the LSO directed each approach and landing by signalling the pilot with his paddles. He literally flew the approach for the pilot. But a significant event altered the LSO's role -- the paddles were replaced by a visual landing aid.

The change in the LSO's role took place in 1955 with the installation of the first visual landing aid. The advent of the jet aircraft had brought with it a requirement for a new method of providing landing assistance to the pilot. The prop pilot had ample time to watch the LSO, respond appropriately to the paddle signals, and receive his "cut" or "wave-off" -- but the jet pilot did not.

First, the increase in approach speeds of jet aircraft required a concomitant increase in the length of the approach to landing. It became obvious to carrier personnel that as the approach distance continued to lengthen with increases in approach speeds, it would no longer be possible for pilots to see the signals given by the LSO with his paddles. A system was required that would provide glide-slope information to the pilot at distances of one mile or more from the ship.

Second, the flat approach formerly flown by the prop pilot to the vicinity of the ramp, followed by either a cut or wave-off signal from the LSO, was not suitable to the flight characteristics of jet aircraft. A flat approach can result in either a "bolter" (the aircraft's hook fails to engage one of the arrestment wires and the pilot reenters the traffic and makes another approach) or a hard landing. A hard landing occurs when sink rate is excessive as a result of the sudden cut in power. Jet aircraft require a constant glide-slope angle approach, with power-on and no cut until the hook has engaged the wire. This means that glide-slope information has to be provided to the pilot continuously to touchdown, well past the point that the LSO would be in view. For these reasons, and others, the visual landing aid system was adopted.

The primary role originally played by the LSO was reduced to a secondary role: the "paddles" LSO would tell the pilot when and what to correct. In the visual landing aid approach, it is first up to the pilot to analyze the approach and effect a solution. If approach performance becomes unacceptable, the LSO will offer corrective assistance.

When the visual landing aid was introduced, and accompanied to introduction of the angle deck, many believed that the LSO had become obsolete and eventually would be removed from the landing process altogether as pilots became proficient in visual landing aid techniques. Others believed that there would always be a requirement for someone to monitor aircraft recoveries, and they suggested that the LSO continue on in that role with the title Landing Safety Officer.

This situation existed for several years. The carrier landing accident rate decreased significantly from the period before the introduction of visual landing aids in 1954 to the period after introduction was largely completed in 1957: the rate decreased from 35 accidents per 10,000 landings in 1954 to nine accidents per 10,000 landings in 1957 -- a four-fold improvement in just four years. This dramatic reduction in the accident rate seemed to confirm the judgement that the LSO would soon be either completely supplanted by the visual landing aid or reduced to the role of safety observer.

Then a number of events took place that eventually were to regain for the LSO the importance and status he had previously been accorded. The reduction in the accident rate began to level off. Although the accident rate slowly continued to be reduced, it remained substantially higher than the accident rate at conventional airfields. The cost of accidents began to rise because of the increasing cost of aircraft, other equipment, and personnel. The percentage of hard landings and ramp strikes increased from approximately 40% of total carrier landing accidents in 1954 to 80% in 1964. The tempo and complexity of carrier air operations increased and operations were extended into more severe environments, night and all-weather operations increased, heavier and faster aircraft were introduced, and the number of different types of aircraft increased. Not only were there more different types of aircraft, but they varied markedly in approach and landing flight characteristics. These changes critically reduced the margin for error in carrier approaches.

The results of these changes was a reassessment of the requirements for the safe and efficient recovery of carrier aircraft. If the accident rate was to be further reduced while the tempo and complexity of air operations increased, pilots would require more assistance in the approach than could be provided by the visual landing aid. Passive information, by itself, was often not enough for successful recovery of aircraft at night, under conditions of limited visibilities and pitching decks. Active LSO assistance, not simply monitoring, was essential for most pilots under these conditions. In the British Navy, the LSO had actually been removed from the carrier landing process after introduction of the visual landing aid but was placed back in the process after the accident rate began to increase.

The LSOs regained the important role that they had previously held in the carrier landing process. However, it was not regained without difficulty. The general downgrading of the visual landing aid was accompanied by a diminishment in the status that had been previously accorded the job. The number of LSOs dwindled, command attention waned, and LSO training and quota requirements were not enforced. The job no longer had the same appeal to pilots now that much of the prestige was removed. The result was a significant decrease in the number of volunteers for LSO training. Not only was the quantity of LSOs affected, but also the quality. The billet no longer appealed to ambitious, career-oriented junior officers. They viewed the billet as being detrimental to their career and preferred to serve in more "career enhancing" billets.

Although the LSO billet regained much of the importance it had lost earlier, status was regained more slowly. Several years passed before a nucleus of LSOs was formed with the personality traits and skills that once again could command the respect of squadron pilots. However, the attitude persisted that the billet was not career enhancing, and the LSO community was unable to attract enough qualified junior officers to fill all of the LSO billets.

The problem of attracting junior officers was compounded by the demands of the billet. The increased complexity and tempo of carrier air operations caused a concomitant increase in the demands of the job. An appreciation of these demands can be gained by examining the unique aspects of the LSO billet that set it apart from other billets in which naval aviators can serve. It requires a longer training period. The average length of training to be able to control a single type of aircraft during both day and night recovery conditions is approximately 15 months -- nearly as long as flight training itself. After this initial qualification, it takes approximately two more years before an LSO is qualified to control all types of aircraft that comprise a carrier air wing, and only a few LSOs are capable of achieving this qualification. Once trained, LSOs remain in the billet longer than their non-LSO contemporaries remain in their respective billets. The average length of time spent in the LSO billet, after training, is six years. LSOs tend to work long and awkward hours: 13 to 14 hour work days are not uncommon, and much of this time occurs in the late evenings and early mornings. These hours are not confined to shipboard deployments. When ashore, LSOs are responsible for the carrier landing training of pilots. Much of this training takes place at night and at sea. It is not uncommon for a training LSO to spend one-third of his shore-based tour away from home. Serving in the LSO billet both during training and after qualification does not reduce in any way the LSO's obligations and responsibilities as a pilot. LSOs once were assigned to carriers as part of ship's company in non-flying status. Today, they are active members of the air wing, participating in all squadron flight operations, in addition to serving as squadron or wing LSOs.

The demands of the LSO billet and the attitude that the billet was non-career enhancing combined to produce serious personnel deficiencies in the LSO billet. These problems, and others, were identified in a study I performed in 1967 for the Office of Naval Research. The purpose of the study was to identify problems that LSOs were encountering in their job that if eliminated would enhance their performance and the overall safety and efficiency of carrier air operations.

Interviews conducted with LSOs during the initial phase of the study revealed that they were most concerned about personnel problems. It was revealed that the demands of the job and the non-career enhancing attitude was not only detrimentally affecting the recruitment of junior officers as trainees, but also the retention of senior LSOs. They were having to devote more hours to the job and more time in the billet to make up for the shortages in qualified LSOs. They felt this was detrimentally affecting their chance for promotion to the ranks of senior officer and selection for squadron command. They reasoned that the extensive training period, the length of time they served in the billets, and the demands of the job, reduced their opportunity to serve in the variety of squadron and wing billets that their non-LSO contemporaries serve in during their careers; and that this caused them to lack the generalized background considered essential by the Navy for optimum career development. As a result, they felt that they did not have the same opportunity as their non-LSO contemporaries for promotion to senior ranks and selection for command. Furthermore, they were able to substantiate this claim by citing examples of senior LSOs who were not promoted or screened.

As part of the ONR study, I obtained data from the Bureau of Personnel that indicated that there was no justification for this attitude. In the most recent year group considered for promotion and selection for command at the time of the study, the LSOs were significantly more successful than their non-LSO contemporaries. Indeed, it appeared that serving in the LSO billet enhanced their chance for promotion and selection for command. I believe that it was true at one time that LSOs were not as successful as their non-LSO contemporaries. However, I believe that this was the result of the officers that were attracted to the billet during the years following the introduction of visual landing aids, rather than their association with the billet. These officers lacked the attributes that the Navy considers important for promotion and selection for command, and therefore, were less successful than their non-LSO contemporaries. Recent data obtained from Bupers indicates that LSOs continue to be more successful than their non-LSO contemporaries in both promotion and selection for command.

The publication of these findings dispelled the attitude that the billet was not career enhancing. Recruitment and retention began to improve. Also, as part of the ONR study, I worked with Bupers to develop an LSO career assignment policy that further enhanced LSO recruitment and retention. This policy is still in use today. To my knowledge, this is the first time in recent history that Bupers has established a special assignment policy within the unrestricted line officer category.

Another problem identified in the ONR problem analysis study was deficiencies in the design of the LSO work station or platform. Deficiencies exist in the design, location, arrangement, and integration of displays and equipments intended to assist the LSO in controlling the aircraft. A major problem is the location of displays of aircraft performance such as speed, glide-slope and line-up discrepancies, range, and so on. These displays, and others, are located in a console at the LSOs' feet and slightly to his right, while the aircraft is approaching from the left and slightly above eye level. The LSO simply cannot take his eyes off the approaching aircraft to look at the displays, particularly in the critical terminal phase of the approach. As a result, the utility of the displays is severely limited.

Gross location is not the only problem. Displays are also not optimally integrated for use by the LSO. Individual displays are positioned on the console without consideration to their priority of importance of the information displayed. Also, the design of individual displays is poor, which further affects their utility. Communication equipment is also inadequately designed and located. And the utility of all the displays and equipments is seriously affected by excessive down time.

At the completion of the problem analysis study, ONR funded a follow-on study to redesign the LSO platform consistent with present and future LSO task requirements. The major result of this study was the design of a new LSO display console. The console was designed to satisfy certain fundamental requirements. First, it relocates displays more in line with the approaching aircraft. The console is mounted on a stand that can be elevated to accommodate the height of individual LSOs and aligned with the path of approaching aircraft. Relocation alone, however, was not enough to provide maximum utilization of the displays. Relocation would improve utility but still would require the LSO to take his eyes off the aircraft to read the displays because of having to change focus. A second requirement then was to adopt a display format that would eliminate the need for changes in accommodation. This was accomplished by adopting a head-up display (HUD) format. Information presented on the HUD appears to be superimposed on the LSOs' forward field of view. Thus, changes in accommodation to monitor the displays are not required.

A third requirement was to improve the LSOs' ability to control aircraft in minimum visibility conditions when he cannot see the aircraft until it breaks out in the terminal phase of the approach. This was accomplished by providing the LSO with an integrated, sensor driven display of line-up and glide-slope information on the HUD as well as sink-rate, speed, range, and deck motion. Displaying this information on the HUD allows LSOs to simultaneously monitor the displays and scan the overcast for the approaching aircraft, thereby providing the LSO with aircraft trend information before he sees the aircraft.

The new console was field tested at Patuxent River in 1973, by approximately 50 LSOs, and evaluated at sea in 1975 on the USS Ranger (CV-61). It is presently installed on two carriers, and plans have been formulated by the Naval Air Systems Command for installation on all other carriers.

I would like to change the topic of discussion now to LSO training. As previously mentioned, the LSO is responsible for controlling aircraft approaches, and during the final seconds of the approach, for making the critical final decision that determines if the aircraft can be safely brought aboard the carrier. In this process, he employs some of the most complex perceptual and judgemental skills that naval aviators are called upon to make. His decision depends upon the perception of subtle visual and auditory cues which vary with different types of aircraft, the idiosyncracies of different pilots, environmental factors such as weather, carrier motion, wind over deck, air wake turbulence, time of day, operational time constraints, and many other factors. Some idea of the complexity of the job is indicated by the amount of time required to become qualified as a squadron and air wing LSO.

Despite the complexity and importance of the LSO's job, LSO training has remained essentially the same since LSOs were first introduced into carrier aviation. No other aspect of carrier aviation training has remained as unchanged, and received so little attention from training specialists. Yet, with the possible exception of landing aboard carriers, no other task performed by naval aviators is more demanding or complex.

LSO training today is performed in the same manner as it was 30 years ago -- informal, on-the-job training. Trainees observe, and later control, approaches under the supervision of senior squadron and air wing LSOs. Guidance for training is provided by rather vague statements of requirements, objectives, and evaluative criteria. The lack of specific guidelines, and the individual differences in the ability of senior LSOs to impart LSO skills, results in a wide range of training effectiveness. Over the years, the LSO community has recognized the need to improve training and has made several attempts to initiate studies. However, until recently, these attempts have been unsuccessful.

The need to improve training received renewed emphasis several years ago when the carrier deployment schedule was changed. Prior to this change, carriers remained in port for approximately 6 to 8 months between deployments. The change increased the in-port period to approximately 13 to 15 months. This means that carrier pilots and LSOs are operating at sea for about half as long as they were several years ago. The reduction in at-sea time reduces the opportunity for pilots to acquire basic carrier landing skills and once acquired, to maintain proficiency in these skills. LSOs, too, have less opportunity to acquire and maintain their skills.

Concern for the effect of the reduction in at-sea time on the safety of carrier operations led CNO, COMNAVAIRPAC, and COMNAVAIRLANT, to convene an LSO meeting in December of 1973 to develop recommendations for reducing the impact of the change in carrier deployment schedules on landing performance. The assumption was that the most practical way of avoiding an increase in the accident rate was through improved LSO performance, because apart from the pilot, the LSO has the most direct influence on the safety of carrier operations. The attendees felt that if LSO performance was to be improved, improvement was most likely to be achieved through training. However, apart from some recommendations for changes in organization, they could not make any specific recommendations for improving training. They felt their job was far too complex to be improved without assistance from training specialists. Therefore, attendees recommended that a training requirements study be performed that would systematically examine their job and develop recommendations for an improved *program* of training -- a goal of the LSO community long before the change in carrier deployment schedule. This recommendation was translated by the Navy into the present NTEC LSO training effort.

The change in carrier deployment schedule created a renewed emphasis on improving training but, at the same time, reduced the opportunity for LSOs to observe and control aircraft at sea -- the most important aspect of LSO training. Therefore, emphasis in the NTEC program has been placed on developing a training technique that will provide a realistic, alternative, training experience. Present shore-based training does not provide a realistic alternative. Although an essential aspect of LSO training, observation and control of aircraft at shore facilities is limited in its capability to prepare trainees for at-sea operations. Differences exist in aircraft approach performance due to the lack of carrier movement and reduced wind velocity. Also, additional visual cues are provided by lights, structures, and surrounding terrain which makes the task of controlling aircraft significantly easier. Therefore, NTEC elected to develop a visual simulator that would provide a realistic and effective simulation of the carrier recovery approach and environment.

However, the goal of the NTEC effort is not limited to providing an alternative training technique for the at-sea experience. It is also intended to provide a more effective overall training program. This will be accomplished by augmenting the at-sea experience with a wider and more diverse range of approaches and recovery conditions than trainees typically experience during carrier deployment. On carriers, approaches cannot be allowed to deteriorate to a point where they become dangerous. Thus, trainees seldom are provided with the opportunity of observing the kinds of dangerous approaches that they are expected to prevent as qualified LSOs. Also, because of safety considerations, senior LSOs are reluctant to allow trainees to control approaches during extreme conditions of limited visibility, pitching deck, aircraft battle damage or malfunction, and so on. Simulator training, on the other hand, is not limited by these constraints. Trainees can be provided with the opportunity to observe and control a wider range of approaches, including approaches that terminate in accidents, under the full range of environmental conditions.

The simulator is also anticipated to provide an effective method of introducing basic skills to new trainees. Approaches can be replayed for detailed analysis and immediate performance feedback. Furthermore, simulator training will not be limited by aircraft/pilot availability and weather conditions.

The need to enhance LSO training has received additional emphasis with the recent change in commercial airlines hiring policy. This change in policy, and other factors, have resulted in a pilot and LSO retention rate of only 27 per cent after the first obligated tour. The result of this change has caused serious deficiencies to develop in the number of qualified squadron and air wing LSOs. These deficiencies make the need for improved training techniques all the more important, especially techniques that will speed the acquisition of basic LSO skills.

However, before an effective simulator training technique can be developed, we must learn more about how the LSO performs his job. In my next presentation, I will describe the carrier landing process in more detail, and the LSO's role in that process in order to underscore the complexity of the LSO's job, and the difficulty of objectively assessing the job for the purpose of developing training requirements.

DEVELOPMENT OF AN LSO
DECISION MAKING MODEL

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INTRODUCTION

Human Performance Research (HPR) was tasked by NTEC to perform a systematic analysis of the LSO's job of controlling aircraft in the final approach and landing phase of carrier recovery operations for the purpose of developing an LSO decision-making model. Dr. Michael McCauley, who is the project director of this study, will describe the study and some of the preliminary results. However, before his presentation, I would like to take a few minutes to describe the LSO's job and the difficulty of analyzing the job.

The Complexity of the LSO's Job

The LSO monitors each approaching aircraft and, if he feels that the pilot requires assistance, will transmit by radio a corrective action. If the pilot fails to respond or if the approach continues to deteriorate, the LSO can exercise his right to terminate the approach by commanding a wave-off.

This is not an easy task. Approach speeds of today's jet aircraft range between 100 and 140 knots. The average duration of the final approach is 30 seconds. With a boarding interval of about 40 seconds during day recoveries, and 60 seconds at night, the LSO must detect deviations in approach performance as soon as they occur, and offer accurate, corrective assistance immediately. He must do this each hour and 45 minutes for approximately 20 recovering aircraft throughout the typical 12-hour period of cyclic operations.

The LSO has two major responsibilities as defined in the CV and LSO NATOPS manuals. First, and most important, he is responsible for the *safe* recovery of aircraft. Second, he is responsible for the *expeditious* recovery of aircraft. Of these two responsibilities, the one that is most often emphasized is the LSO's responsibility for the safety of the recovery. Many people who lack first-hand knowledge of carrier operations view the LSO as an arbiter of pilot performance who monitors the approach and issues judgements in the form of wave-offs whenever an approach deviates from some acceptable standard of performance. Furthermore, many people believe that approach performance is, for the most part, optimum, and that substandard approaches are infrequent and confined, largely, to inexperienced pilots. The fact of the matter is that the vast majority of approaches deviate in some way from optimum performance. Optimum performance is the exception rather than the rule. Deviations occur, and under severe weather conditions during night recoveries, they can be quite large. How does this affect the LSO? It brings into conflict his major responsibilities for both the safe and expeditious recovery of carrier aircraft. To expedite the recovery, the LSO must often work closer to the extremes of acceptable performance than he would if safety were his only consideration. Whether to allow a marginal approach to continue in the expectation that it can be corrected through assistance, or to terminate it by commanding a wave-off is a decision that requires the utmost skill and knowledge of the LSO. Five aircraft performance parameters are available to the LSO for judging aircraft approach performance--glide-slope, line-up, power, attitude, and speed (or angle of attack). Approach performance parameters are perceived primarily by visual cues, although auditory information about aircraft power also is important. The judgemental process can be divided into two tasks. First, the LSO must discern deviations from optimum performance. This task requires the LSO to judge whether or not the aircraft parameters have deviated from an optimum state and to judge the amount of deviation. For example, the LSO must judge whether or not the aircraft is properly lined-up. Second, the LSO must discern the rate of change in aircraft parameters, regardless of whether or not they are optimum. For example, the LSO must judge whether line-up has changed or is changing from its immediately preceding state.

The LSO judges approach performance and offers corrective assistance to the pilot, when required, to correct deviations in approach performance. However, there is a point in the approach beyond which the LSO's control over the aircraft is limited. This point is the result of a time lag that exists in both aircraft engine and pilot response. In aircraft, it is a lag in engine response time to changes in power setting. In pilots, it is the lag between detection of a deviation in approach performance and the initiation of an effective correction, or between the time that the LSO calls for corrective action and the pilot initiates that action.

These time lags limit the corrective action that can be taken to prevent carrier landing accidents to a point well before the aircraft crosses the ramp of the carrier. If an aircraft goes below the glide-slope late in the terminal phase of the approach, the engine response lag, pilot response lag, or both, may preclude LSO corrective assistance from preventing an accident.

The specific point in the approach where the LSO's control becomes limited varies with aircraft type, pilot proficiency, immediately preceding glidepath performance, and other factors, but it can be regarded as approximately one or two seconds before reaching the ramp of the carrier. The LSO's objective is to ensure that the aircraft is established in an optimum or near optimum state for recovery *before* reaching this point.

The LSO's task is twofold. He must first decide whether or not the aircraft is in an optimum or near optimum state. If deviations exist and changes are not taking place that will eliminate these deviations, he will issue a wave-off. If performance is acceptable, the LSO must then decide whether or not it will remain acceptable during the final one or two second period of the approach. He does this by *predicting* performance.

Predicting performance is an essential aspect of the LSO's job and is not limited to the terminal phase of the approach. Throughout the approach the LSO is using his predictive capability to prevent deviations so that the aircraft will arrive at the decision wave-off point in an acceptable state for the landing. He does this by judging the deviations and rates of change that exist at a precise moment in time and then extrapolating the future state of the aircraft. The LSO is continually extrapolating because his ultimate objective is to bring the aircraft to the decision wave-off point with its various parameters falling within very narrow limits. Where the aircraft is at any precise moment in time is almost never as important as where it will be. Predicting future parameter values from instantaneous parameter values is undoubtedly the most difficult task performed by the LSO. (Borden, 1969.)

Lack of recognition of the limits of LSO control has led people to believe that the LSO should be able to prevent all carrier landing accidents. Unfortunately, this isn't true. If the pilot makes an improper control action after passing the decision wave-off point, there may be very little the LSO can do to prevent an accident from occurring. The majority of accidents in which the LSO is cited as a causal or contributing factor probably do not occur because the LSO failed to detect a deviation in performance, but because the LSO failed to accurately predict approach performance for the final one to two seconds before crossing the ramp.

The purpose of this description of the LSO's job is to underscore its complexity, and, therefore, the difficulty of examining the job for the purpose of developing a training program. The authors' understanding of the LSO's job is based entirely on observation of the carrier recovery process and interviews with LSOs. It lacks the rigorous, systematic examination required for development of a training program. We do not know, for example, the approach parameter values judged as acceptable performance by LSOs and the effect on these values of such factors as weather, pilot proficiency, LSO proficiency, carrier deck motion, and so on. The largest source of variability may be the LSO's dual responsibility for both the safe and expeditious recovery of aircraft. However, the values of acceptable performance and the factors that influence these values cannot be determined without conducting a rigorous examination of the LSO's job.

STUDY PHASE I

The study tasks to be performed by HPR were: 1) analyze the decision making process of the Landing Signal Officer (LSO) during carrier aircraft recovery operations; 2) identify aircraft approach parameters that are used by LSOs to judge approach performance; 3) identify situational and environmental variables that influence the LSO's task; 4) estimate the LSO's decision criteria for issuing corrective assistance calls to the pilot; 5) catalogue and analyze the standard and non-standard verbal responses commonly used by LSOs; 6) suggest candidate performance measures applicable to an automated LSO trainer; and 7) synthesize this information in an LSO model suitable for translation to software for application in an automated LSO training device.

Methods

The analytic methods used in the first phase of the study were observation, interview, and review of literature and documentation.

Carrier landing operations were observed both ashore and at sea. More than 250 Field Carrier Landing Practice (FCLP) approaches of A-7 aircraft were observed, and over 700 carrier approaches were observed from the LSO platform aboard the USS Coral Sea and the USS Enterprise.

Informal interviews were conducted with approximately 20 LSOs. Later, structured interviews of approximately two hours length were conducted with LSOs individually and in group sessions. The purpose of the structured interviews was to specify under what circumstances standard NATOPS LSO calls would be used.

Results

The analytic data were used to develop the LSO decision making model or flow-chart model, which is presented fully in Borden and McCauley (1978). Although it is too lenghty to be reproduced fully in the present paper, an excerpt of the flow-chart model is given in Figures 1, 2, and 3, which show the Start Loop, Low Procedure, and Low (A) Procedure, respectively. The remaining subroutines in the model, not included in this paper, are the following: High, Line-Up, Multiple Deviation, Sink, Climb, Drift, Speed, Begin, and End.

The LSO flow-chart model is an attempt to represent what a standardized LSO would do, under normal circumstances, in response to different combinations of aircraft approach dynamics. A distinct lack of standardization in the LSO community assures that no single LSO would behave exactly like this model. Although it is a model based on consensus, every individual LSO would disagree with something in the model.

An elementary version of the model also was developed, the LSO Call Listing Format Model. This format lists all LSO NATOPS calls and forms a matrix of 62 calls by 10 aircraft approach variables. For each LSO call, the values of aircraft variables that would elicit the call were estimated. The Call-Listing Format ignores many of the sequential dependencies that are included in the flow-chart model. But the listing format includes important situational variables as well as expected pilot response, related LSO strategies, and common non-standard (alternative) LSO calls (Borden and McCauley, 1978).

Conclusions

The LSO decision making model is far more extensive than any previous effort at LSO modelling. However, the estimated values of aircraft approach variables that constitute the LSO decision criteria were based on interview data. Empirical measures of the aircraft approach and the coincident LSO calls were needed in order to quantify the LSO decision making model. The LSO flow-chart model serves as a form of task analysis of the LSO's job during a final approach, but in order to serve as a criterion for LSO-trainee performance, the model requires quantitative support.

STUDY PHASE II

The limitations of analytic methods were recognized at the outset of the study, but obtaining accurate measures of approach performance was thought to be cost prohibitive, requiring instrumentation of both the carrier and the aircraft. The fact that no empirical data have been published relating aircraft approach variables to LSO performance, attests to the difficulty of obtaining quantitative measures.

During the analytic evaluation, HPR identified a measurement method called the Photo Data Analysis System (PDAS) that appeared to have the needed capability to accurately measure aircraft approach dynamics without extensive equipment needed at the landing area or aboard the aircraft. The PDAS is installed at various Naval Test Facilities to analyze the initial stage of aircraft weapon performance, called "store separation."

The PDAS method involves cinematography of the moving object, sometimes at very high frame rates. The film is analyzed, frame by frame, by superimposing the filmed image of the object with a video image of a 3-D scale model of the object. The two images are projected onto a high resolution cathode ray tube by video mixing. The scale model's position is controlled by the PDAS operation through a six-degree-of-freedom model positioner. When the images are superimposed, in the judgement of the PDAS operator, data are automatically recorded by a keypunch and, later, processed by computer. Spatial measurements in six-degrees-of-freedom are obtained from each film frame, and sequential analysis of frames yields measures of rates and accelerations (Cooper and Kingery, 1974).

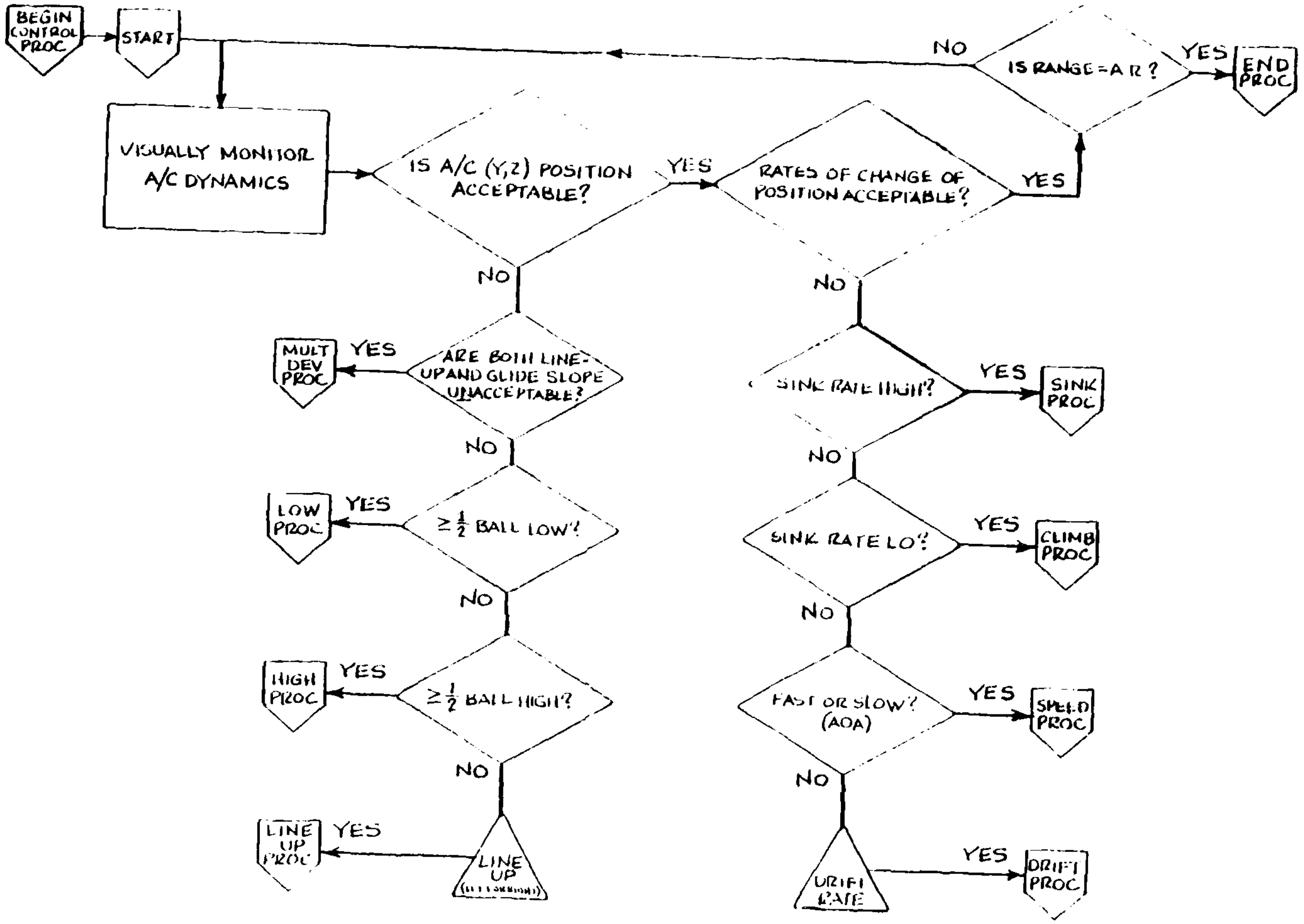

Figure 1. The LSO Flow Chart Model: Start Loop.

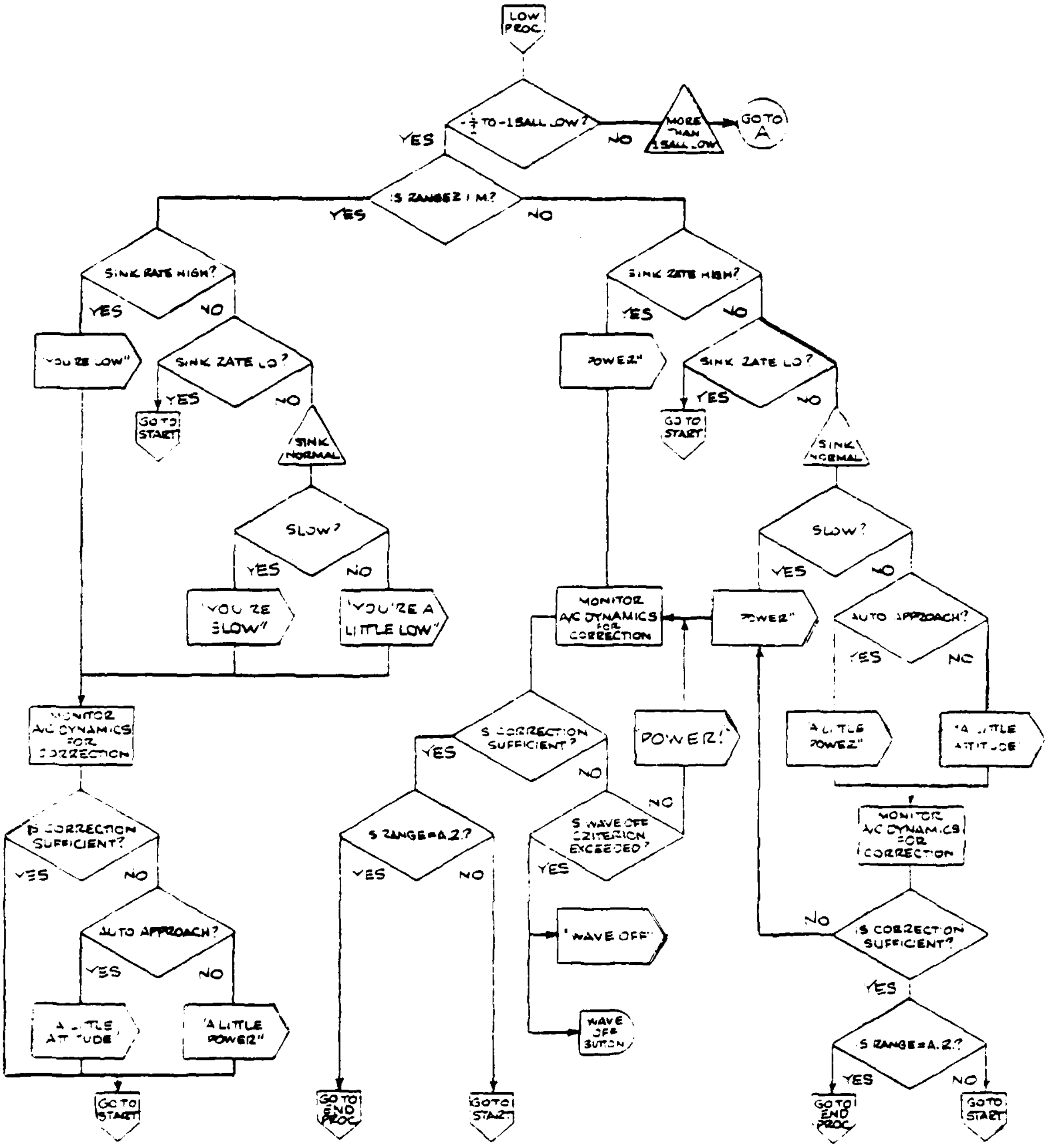

Figure 2. The LSO Flow Chart Model: Low Procedure.

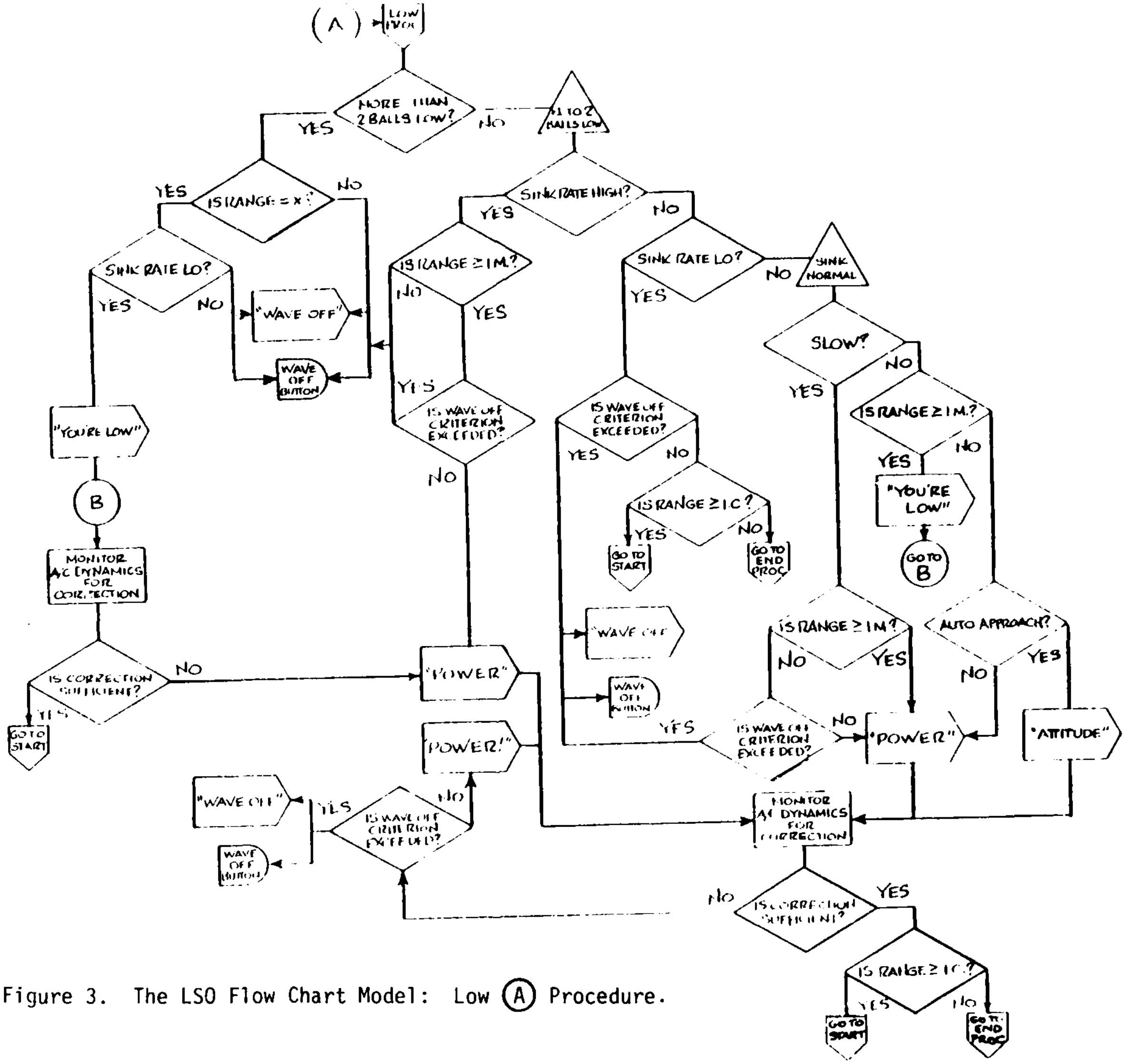

Figure 3. The LSO Flow Chart Model: Low (A) Procedure.

HPR proposed to use PDAS for obtaining measures of aircraft approach variables while LSO calls were being recorded.

Methods

Several data collection methods for subsequent PDAS analysis were investigated, including filming approaches aboard a carrier, analyzing the existing Pilot/LSO Landing Aid Television (PLAT) videotapes of carrier landings, and filming FCLP approaches. The first two methods were eliminated due to the difficulty of platform motion compensation. PDAS analyses of ship-board films would be feasible in cases where some object appeared in the field of view, such as the plane guard destroyer, to provide a calibration datum.

The present study limited the data collection to night FCLP approaches of A-7E aircraft at NAS Lemoore. FCLP data collection eliminated the motion compensation problem, and enabled multiple LSOs to simulate "waving" the aircraft.

Nearly 250 FCLP approaches were filmed, and one to four qualified LSOs simulated controlling each approach as if it were a carrier approach. The film and the audio recording of the LSOs were synchronized by a time code generator.

Analyses and Results

Audio Analysis. HPR analyzed the audio recordings of the LSO calls during FCLP data collection. Nearly 1000 LSO-waved approaches (250 approaches x 4 LSOs) were analyzed. Each LSO call was logged, with the time of onset to the nearest second. An example of independent action from 3 LSOs on the same bad approach is given in Table 1.

The three LSOs all detected the (simulated) dangerous situation and used nearly identical calls to counteract it. It is interesting to note, however, that LSO #1 gave two calls for power before LSO #3 gave the first one.

Video (PDAS) Analysis

At Point Mugu, the PDAS analysis of FCLP films has been delayed by a series of events including software development, higher priority projects, and recalibration of a long camera carriage track following an earthquake. We are happy to report that over half of the data now have been analyzed. Presently, the data are limited to the last 15 seconds of each approach. PDAS analysis of the data for the first 7-10 seconds of each approach is scheduled for completion this month.

Figures 4 and 5 represent approach attitude by range for two approaches called "good flight" and "bad flight," respectively. The "bad flight" (Figure 5) is the same approach as in Table 1, where the calls from 3 LSOs were described. The data rate in the PDAS measures is two per second, therefore, each cross on all of these figures represents the position/orientation of the aircraft at half-second intervals. Some calibration has yet to be incorporated in software, so these and subsequent figures should be considered only as preliminary examples of PDAS data reduction.

The three dimensional position of the aircraft ("good flight") as a function of time is shown in Figure 6--range, line-up, and altitude. The three dimensional orientation of the aircraft over time is shown in Figure 7--pitch, bank angle, and yaw. The software calibration for yaw has not been completed. Similar figures are

TABLE 1. RECORDINGS OF 3 LSOs INDEPENDENTLY "WAVING" AND COMMENTING ON THE SAME BAD FCLP APPROACH

TIME	LSO 1	LSO 2	LSO 3
20:41::13	A little Power		
41::14	Power	Power	
41::15	Wave-off	Power	Power
41::16		Power! Power!	Power!
41::17			Wave it off!

LSO Comments: LSO 1 - "May have rotated and hit the ramp on that one;"
LSO 2 - "Looked like a ramp strike;"
LSO 3 - "Close to a ramp strike."

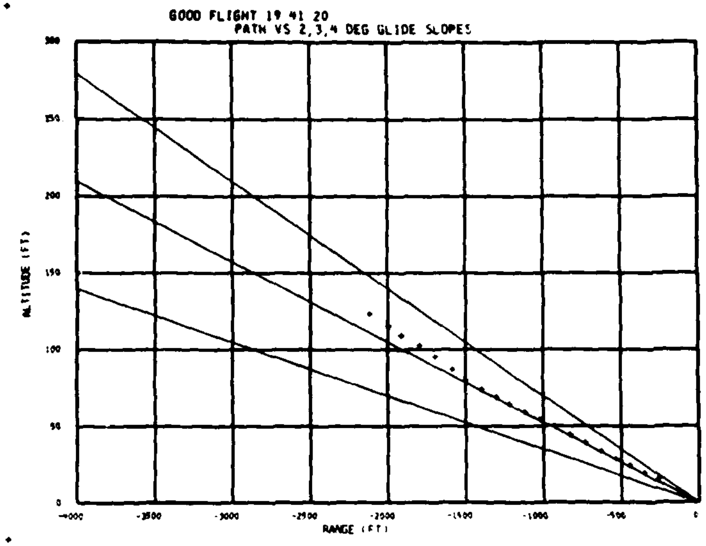

Figure 4. Altitude by Range for "Good Flight."

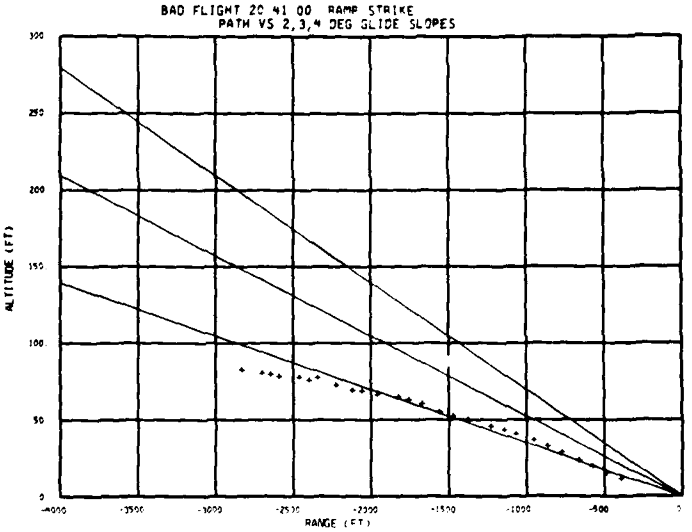

Figure 5. Altitude by Range for "Bad Flight."

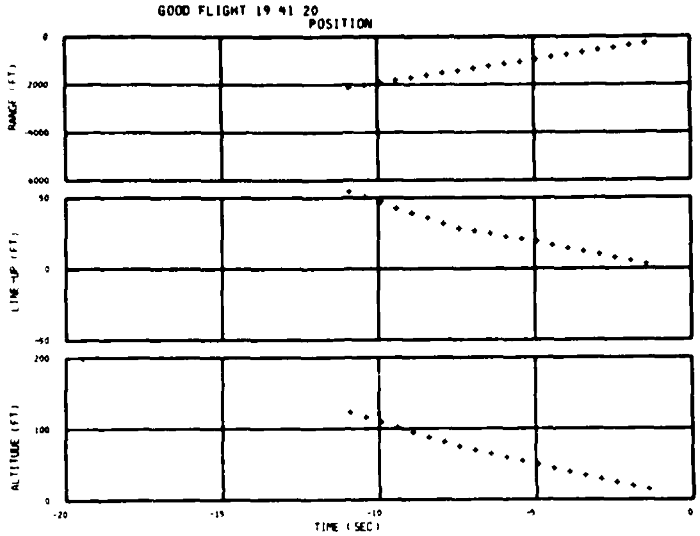

Figure 6. Aircraft Position as a Function of Time, for Three Axes.

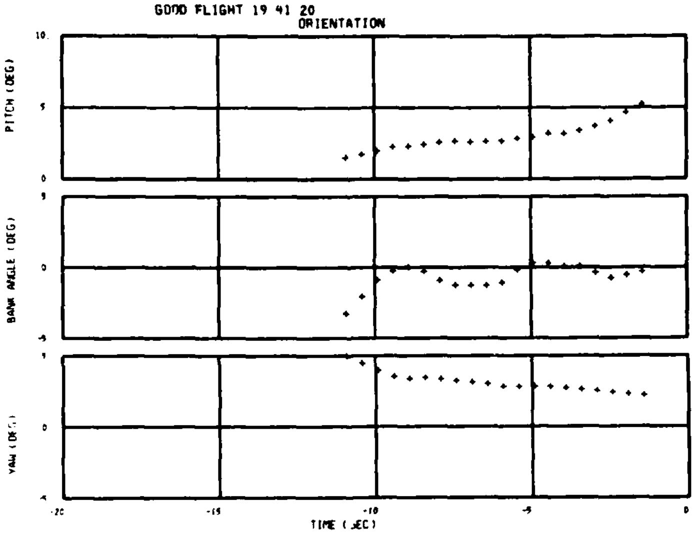

Figure 7. Aircraft Orientation as a Function of Time, for Three Axes.

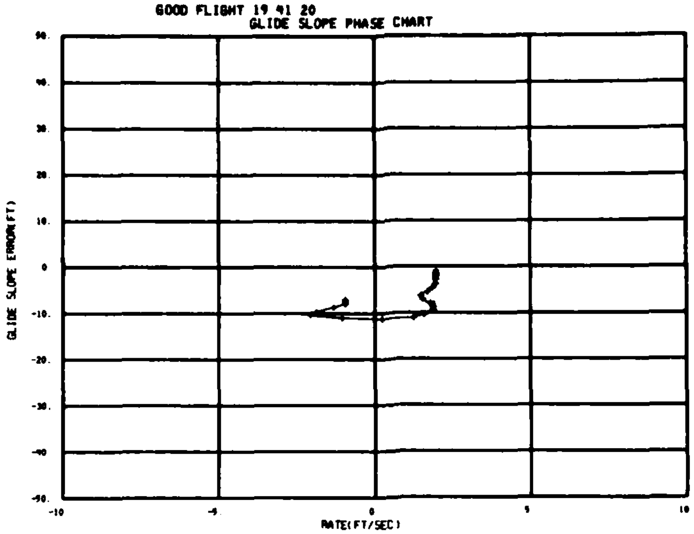

Figure 8. Glide Slope Phase Plot for "Good Flight."

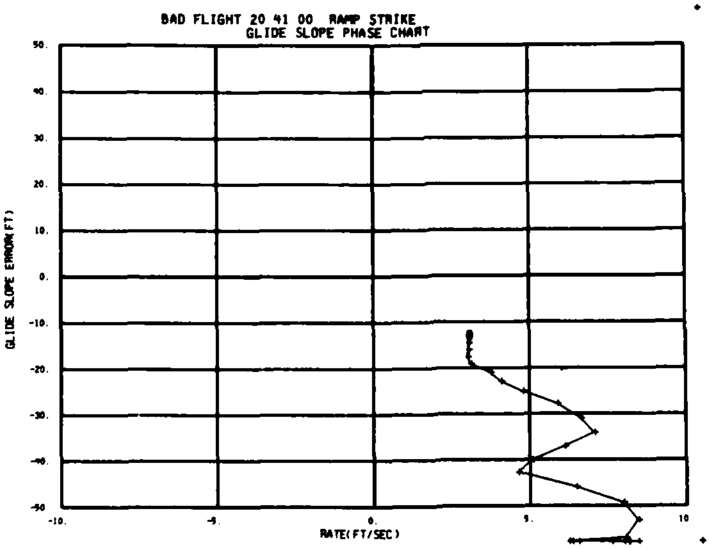

Figure 9. Glide Slope Phase Plot for "Bad Flight."

available, although not shown here, for velocities over time--sink rate, drift rate, and closure rate (ground speed, for FCLP).

An experimental phase plot of glide slope by rate-of-change of glide slope is shown in Figure 8 for "good flight."* The same type of phase plot is shown in Figure 9 for "bad flight." Each cross represents the combination of glide slope position error and rate-of-change of glide slope position (analogous to climb or sink). Consecutive crosses are one-half second apart, and the terminal (landing) datum is represented by a circle. Note that "good flight" was always between 0 and -12 feet from a 3½° glide slope, and sink rate (relative to glide slope) ranged from about 2½ ft. per second sink to 2½ ft. per second climb. By contrast, "bad flight" (Figure 9), began more than 50 ft. below glide slope, and had a positive rate (climb relative to glide slope) throughout the approach. However, the climb rate decreased over the last six seconds of the approach, and was insufficient to assure ramp clearance. At approximately 2 seconds prior to the circle, representing touchdown, the data point (aircraft center of gravity) is about 17 or 18 feet below glide slope.

LSO Modelling

The aircraft approach measures from PDAS, when combined with the results of the LSO calls analysis, will provide the data necessary to estimate LSO call criteria. Each time a particular LSO call is used, the aircraft parameters at that time will be saved in a data bank. Using these data, statistical distributions will be obtained for each LSO call, enabling the mean values, for example, of the critical aircraft variables to be specified for a particular LSO call. Data from individual LSOs will be compiled separately, and this will allow individual differences to be noted and analyzed.

If time and funding allow, techniques such as those based on signal detection theory will be applied, to investigate differences in LSO sensitivity and bias to approach deviations.

The data relating aircraft approach variables to LSO actions will provide a basis for establishing LSO training criteria and performance measurement, either for an automated training system, or a performance evaluation aid for the LSO Instructor in a non-automated system.

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*Thanks to Don Vreuls of Vreuls Research Corporation for suggesting the Phase Plot.

BIOGRAPHICAL SKETCHES

Mr. Gail J. Borden is President of Human Performance Research, Goleta, California. He has a B.A. in Psychology from the University of Southern California. A former Naval aviator and instructor in navigation and air traffic control procedures, Mr. Borden has been engaged in research since 1960, specializing in aviation psychology. He has directed studies on topics such as geographic orientation in pilots, air traffic control, and the carrier aircraft recovery process, with emphasis on the LSO. He designed a heads-up-display for the LSO workstation, and has performed design studies for other carrier workstations including CATCC, PRIFLY, and the Captain's Bridge. Mr. Borden is currently conducting an operations analysis of Combat Information Center.

Dr. Michael E. McCauley is a Staff Scientist at Canyon Research Group, Inc. in Westlake Village, California. He has been actively involved for twelve years in basic and applied problems in human perception and performance. He served as a naval officer in the capacity of Aerospace Experimental Psychologist, where he conducted research on vestibular and auditory processes and provided human factors engineering support for patrol ASW operations. His work with private research corporations, since 1972, has included research on human response to whole-body motion, performance test battery development, LSO model development, and evaluation of automated training systems. He received the M.A. degree in experimental psychology in 1968 from the University of Hawaii, and Ph.D. in 1979 from the University of California Santa Barbara, specializing in perceptual-motor performance.

LSO PERFORMANCE MEASUREMENT

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RESEARCH BACKGROUND

The Landing Signal Officer (LSO) as an element of the overall aircraft carrier landing system, contributes substantially to the quality of landing performance.

This is especially true at night and under less than optimum conditions. While the importance of the LSO's contribution to overall carrier landing system effectiveness is not disputed, relatively little is known about the variability of his performance or his actual effect on the system. In addition, the previous lack of objective landing performance criteria for evaluating carrier landings and the contribution of the LSO to the quality of those landings has up to now prevented any quantitative estimates of LSO performance variability. Past research has necessarily focused on subjective data (e.g., LSO/pilot opinion questionnaires) and intuition in the absence of objective and quantifiable performance criteria.

A number of significant training and operational problems could be more reliably approached with a quantitative, objective measure of LSO performance. For example: How much training is necessary for satisfactory LSO performance? What is satisfactory performance? What are the LSO waveoff boundaries for different aircraft? What is the transfer of training effectiveness of LSO simulator training? Does LSO performance vary across aircraft type and/or model? Is LSO performance "better" with aircraft they themselves fly or is ability sufficiently generalizable such that an LSO can wave all aircraft with equal effectiveness? Do LSOs lose their "seaman's eye" with extended layoffs? What is the optimal lay-off interval between periods of LSO landing experience? How much "waving" is necessary to bring an LSO back up to his normal performance level after extended layoffs? Does Performance of some or all LSOs degrade under pitching deck conditions? Finally, what are the standards for LSO performance? Answers to these and other equally critical questions could be provided if objective measures of LSO performance were available.

PREVIOUS RESEARCH. The purpose of this research was to investigate methods for the objective measurement of LSO performance effects in carrier landing system performance. In previous years we have gathered quantitative, empirical data on thousands of day and night carrier approaches. Experienced and inexperienced pilots, seven jet aircraft types, and dozens of LSOs were observed and measured on aircraft carriers under a variety of environmental and shipboard conditions. Briefly, those data included continuous measurement of error from optimal glideslope and centerline as well as sink speed, airspeed, range, deck pitch, arrestment wire, bolter and waveoff information for day and night approaches. A number of previous studies have reported the data and have described a variety of pilot-related carrier landing performance topics such as day and night landing performance,[1] landing performance under combat conditions,[2] high workload operations,[3] operational measures of carrier landing system performance,[4] predictions of pilot landing performance[5,6,7] and visual landing aid evaluation.[8] Equally important to this research were the studies[9] of criterion development, test and validation. While other researchers have attempted qualitative approaches to the criterion problem[10,11] none have obtained fleet data in objective terms related to job performance.

Past LSO studies[12] have pinpointed through questionnaire data that perceptual ability is the major cause of attrition during LSO training. A related study[13] measured LSO perceptual ability to determine the range of perceptual ability or "seaman's eye" that exists among fleet qualified LSOs as well as LSO trainees. More recent LSO studies have concentrated on analytic techniques to enhance the design and development of LSO training systems. One study[14] developed an LSO decision model for application in an automated LSO training device. Another report[15] analyzed the performance capabilities requirements for the same automated LSO training device. The later report is especially useful as a reference work which describes, in detail, the LSO job and current training.

The research reported here reports specifically on fleet qualified LSOs and describes the variability of their performance using objective measures of carrier landing performance to assess and describe the accuracy of their "seaman's eye."

TECHNICAL APPROACH

A systematic, analytic approach was used in developing candidate measures of LSO performance. The approach was designed to describe, in quantitative terms, the relative effectiveness of the LSO in performing his functions in carrier recovery operations. By relating the performance measures to LSO aircraft recovery functions, job relevant measures with inherent face validity can be provided. The technical objective was to provide practical performance measures that could be used to describe relative variations in LSO performance across day and night recovery as well as providing the basis for the eventual development of LSO job performance and training standards.

CARRIER LANDING SYSTEM ANALYSIS. The carrier landing system is defined as consisting of four primary sub-systems--ship, aircraft, pilot, LSO--and the environment in which it operates. Each contributes to total system performance effectiveness. The results of factoring out the effects of each of the subsystems and their relative contributions to total system performance would be extremely useful, but, given the available data and the complexity of system interplay, does not appear feasible at present. However, the performance variability within each of the subsystems can and has been explored.[1,8,16] The LSO measures considered here are truly system performance measures--not simply LSO performance measures--since they are the combined result of pilots landing airplanes on ships with the help of LSOs. Although the pilot still controls the aircraft, and probably is the prime contributor to system performance effectiveness, the LSO is considered to be an active control element in the system which provides feedback to the pilot on the quality and acceptability of his final approach performance.

While absolute levels of pilot or LSO performance cannot be extracted from the overall carrier landing system performance, relative differences in system performance as a function of different pilots or LSOs can be accurately described. By holding the ship variable constant (or limited to one ship for representative samples) and assuring the LSOs have relatively equal exposure to samples of pilots, aircraft types and models, and environment, then any quantitative performance differences observed among LSOs can be considered true differences within normal statistical sampling errors. Similarly, if, on a single ship, a sample of pilots flying a specific aircraft model are equally exposed to a group of LSOs, observed differences among pilots can be considered true differences within sampling error. Our previous research has isolated the effects of pilot performance, aircraft types and ship size. This study will focus on measurable differences in LSO performance during fleet operations and under the preceding assumptions. Although carrier landing performance measures represent total system performance, LSO related performance differences can be partialled out of the systems measures if all LSOs operate under statistically equivalent ship, aircraft and pilot conditions. A review of the samples selected from the carrier landing data bank support that assumption.

While we have successfully evaluated approach measures of performance, i.e., altitude and lateral error, sink rate, speed, etc., a simpler performance measure was desirable. One such measure was the terminal state of an approach, that is the wire number of arrested approaches, bolters or waveoffs. Approach terminal state measures are accurate estimates of approach performance due to the correlation which has been shown to exist between them. As an example, distance down the deck (e.g., wire number) is highly correlated (.82) with altitude and sink rate approach performance measures near the ramp which in turn are highly interrelated with one another at distances to 1/2 mile from touchdown.[5] Consequently, simple wire number, by virtue of its correlation with approach performance, has been found to be a very reliable estimator of approach performance. Thus, one way to estimate LSO effects on approach performance is through measures of terminal landing conditions such as wire number, bolters, and especially LSO initiated waveoffs. The latter category is particularly relevant to the LSO's role as a safety monitor.

Application of these same terminal landing conditions as measures of pilot landing performance has been successfully tested and validated[9] and forms the basis for the technical approach followed here. The emphasis, however, has been shifted from the pilot to the LSO. The variability of LSO performance has been partialled out of the carrier landing system performance to allow a description of LSO performance across different operating ships, aircraft and environments.

LSO ROLE IN SYSTEM PERFORMANCE. The LSO performs two distinct functions in the aircraft carrier landing system. According to the LSO NATOPS Manual his primary responsibility is the safe and expeditious recovery of aircraft aboard ship.

LSO ROLE AS SAFETY MONITOR. The LSO operates in parallel with other system elements as a safety monitor when he applies various criteria and decides to wave off or accept an approach during the final seconds before touchdown. His ultimate criterion is successful recovery. The LSO as a safety monitor has been investigated to some extent through accident studies in terms of contributory causal factors but not objectively in terms of safety criteria, and how, and when he applies them and with what results.

LSO ROLE IN EXPEDITIOUS RECOVERY. The second LSO role, one which has been neglected to a greater extent probably due to the inherent difficulties in its investigation, is that of expeditious recovery. Here the LSO acts as an active control element operating serially with other elements in the landing system. As an active control element, the LSO continuously monitors and evaluates aircraft approach performance and initiates voice commands to the pilot as he feels necessary to expedite safe recovery. Those commands take the form of: 1) control commands, e.g., power, 2) directional error, e.g., high/low, 3) error magnitude, e.g., little high/low, and 4) error predictions, e.g., going high. Functionally, the calls are categorized in the LSO NATOPS Manual as informative, precautionary, and imperative calls.

The goal of acting as a controller is to assist the pilot continuously in optimizing aircraft glideslope, attitude, speed, sink rate, etc. such to achieve arrestment on the number three target wire. To the extent that the LSO is able to "guide" the aircraft into what might be called a desired tolerance window for a given set of circumstances, landing system effectiveness is enhanced. Likewise, to the extent that one LSO is better able to monitor and guide aircraft to that window during its approach, than is another LSO, the former can be said to be performing "better" as a system element than the latter.

METHOD

DATA SAMPLE CHARACTERISTICS. LSO performance data analyzed for this study were obtained from a carrier landing data bank that totals over 25,000 day and night carrier landing records collected under a wide variety of ship, aircraft, pilot, LSO and environmental conditions. The samples selected for primary analysis were taken from the existing data bank, and therefore, represent an ex post facto analysis of LSO performance.

The samples were selected for analysis on the basis of several criteria. First of all, a sample was needed which would reflect actual LSO job performance under operational conditions with fully qualified pilots, a typical variety of jet aircraft and a suitable number of day and night recoveries across a normal period of flight operations. A combat sample of F4, A6 and A7 aircraft operating on CV-63 off Yankee station in the hottest air stages of the Viet Nam war satisfied the above criteria and represented the final culmination of LSO training--experienced LSOs waving fleet qualified pilots during combat operations.

A second sample was selected to explore LSO training performance under typical Fleet Replacement Squadron (FRS) conditions. A combined sample consisting of FRS LSOs conducting carrier qualification (CQ) trials for A7 and F4 student pilots satisfied the need for qualified LSOs working with inexperienced pilots. Together, these two samples were considered representative of the wide range of LSO job performance in fleet and training environments.

The two samples are characterized as follows:

Sample One: Combat

- Sample size -- 1718 day/695 night approaches
- Aircraft Types -- F4, A6 and A7
- Environment -- Combat operations in Viet Nam
- Ship -- CVA-63, 3rd line period
- Pilots -- Combat ready
- LSOs -- Experienced, fleet qualified

Sample Two: Carrier Qualification

- Sample Size -- 150 night landings
- Aircraft Types -- F4, A7
- Environment -- Carrier Qualifications (CQ) Training
- Ships -- CVA-60, CVAN-65
- Pilots -- Inexperienced
- LSOs -- Experienced
- Radar records with synchronized LSO calls

LSO PERFORMANCE MEASURES. In order to provide objective performance data for the two LSO functions a number of candidate performance measures used in previous carrier recovery studies were analyzed. These measures were categorized as either terminal or final approach measures.

TERMINAL LANDING MEASURES. Terminal landing measures used to describe, summarize and compare LSO performance, mostly for the function of expeditious recovery, include:

- Boarding rate -- defined as the number of wire arrestments divided by the total number of approaches times 100.
- Unsuccessful approach rate -- defined as the number of technique waveoffs and the bolters divided by the total number of approaches times 100. This measure may also be calculated by subtracting the boarding rate from 100 percent.
- Final approach outcome distribution -- a descriptive technique used to display the relative percentages of 1, 2, 3 and 4 wire arrestments, technique waveoffs and bolters.
- Landing Performance Score (LPS) -- a weighted measure derived from a previous study[6] which reflects the relative importance of each type of final approach outcome. The weightings used for the LPS are based on an interval scale and represent a single quantitative value for each landing category.
- Final approach outcome profile -- a comprehensive summary of all terminal landing measures by LSO.

FINAL APPROACH RADAR MEASURES. All of the above measures and descriptive techniques provide a means to compare the terminal outcome performance of a series of approaches. Although these techniques summarize an LSO's performance as a safety and control monitor they do not describe the final approach leading up to the landing outcome. By obtaining knowledge of the final approach process one may obtain a better understanding of the LSO's function during carrier recovery. One technique for obtaining final approach information is through the collection of precision radar records (SPN-42) along with synchronized LSO calls. These latter data readily provide knowledge of an LSO's effectiveness as a safety monitor and control monitor and are described in the sample of CQ data.

LSO VOICE CALL ANALYSIS. LSO voice calls were manually recorded for a small sample of CQ trials during which each LSO verbal response was annotated to the radar record to provide a match-up of aircraft flight path and LSO call response. The records are analyzed for information on the type, frequency, range, and effectiveness of different calls by LSO and aircraft type.

ANALYSIS OF UNSUCCESSFUL APPROACHES. Unsuccessful approaches such as technique waveoffs and bolters are analyzed for information on the effectiveness of LSOs as safety monitors. The range at which the waveoff was initiated by the LSO, the percentage of unsuccessful approaches among LSOs and an analysis of LSO control effectiveness for unsuccessful approaches are used for descriptive and comparative purposes.

DATA LIMITATIONS. As in many field studies, experimental manipulation of independent variables of interest was not under our control. Consequently, the vast amount of data in the data bank were partitioned after the fact into categories appropriate for the specific LSO analyses described below. One of the principal classifications of data was that of identifying LSOs waving each approach for two major data samples.

The reliability of descriptive statistical measures may be a function of the sample size. While they are typically large for gross catefories, e.g., day vs. night, sample size reduces rapidly with further partitioning, e.g., day vs. night x LSO x aircraft type. In some cases partitioning resulted in sub-sample sizes too small for meaningful comparisons. Consequently, some comparisons of subcategories could not be reasonably made because of the small number of cases involved. Where possible, which was for the majority of cases, LSO x aircraft was compared, and no systematic differences were noted other than those mentioned in the analysis section.

In making reliable comparisons among LSOs, it was necessary to assume that LSOs, in the long run, wave different aircraft types with equal frequency since some aircraft are known to be better, on the basis of accident rates and boarding rates, than others. The assumption was tested by comparing the frequency distribution of aircraft types across LSOs and appears valid for this data sample. No LSO waved one aircraft type significantly more frequently than another.

It was also necessary to assume that LSOs waved pilots of equivalent ability. Fortunately, this assumption does lend itself to direct verification since identification of "good" and "poor" pilots was possible through previous data analysis. The assumption appears logically valid, i.e., there is no reason to suspect that LSOs systematically wave only good or poor pilots. Rather, each pilot was considered qualified to land aboard ship in that aircraft type. Thus, it was assumed and verified that pilot ability did not systematically bias LSO comparisons.

RESULTS

COMBAT SAMPLE. Results from the analysis of aircraft recovery during combat operations off the coast of Viet Nam, where both pilots and LSOs were highly trained and experienced, are shown in a series of figures which describe LSO performance variations during night carrier recovery. Data are presented in four figures to provide a comprehensive summary of LSO performance:

- Boarding Rate
- Unsuccessful Approaches
- Landing Performance Scores (LPS)
- Final Approach Outcome Profiles

NIGHT BOARDING RATE. LSO night boarding rates are illustrated in Figure 1 across ten LSOs with a sufficient number of night approaches (>25) to justify calculation of descriptive means. For all LSOs the boarding rate was 93 percent, ranging from a high of 100 percent successful (LSO #1) to a low boarding rate of 88 percent (LSO #6). The variability range was only 12 percent between highest and lowest performing LSOs for this line period.

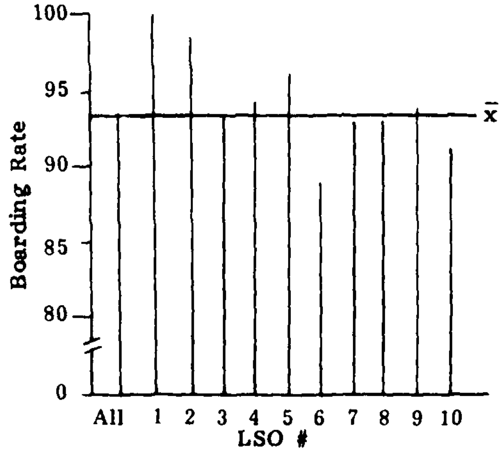

Figure 1. Night Boarding Rate by LSO Across All Aircraft Types for Combat Sample.

In terms of LSO functions, since there were no landing accidents, each LSO was successful in his safety monitor role. Looking at his role in expeditious recovery a 93 percent night boarding rate was achieved. This can be considered a very successful line period compared with fleet-wide night boarding rates that averaged in the low eighties for most operations.

NIGHT UNSUCCESSFUL APPROACHES. Another way to look at LSO performance besides boarding rate is by analyzing unsuccessful approaches. In this case unsuccessful approaches are defined as technique waveoffs or bolters.

LSO unsuccessful approaches are graphed in Figure 2. Across LSOs 7 percent for all approaches were unsuccessful, ranging from 5 percent for bolters to 2 percent for waveoffs. LSO number one had no unsuccessful approaches while LSO number six had 12 percent of his approaches result in either bolters (10 percent) or waveoffs (2 percent). LSO number two had no bolters while LSO number five had no waveoffs.

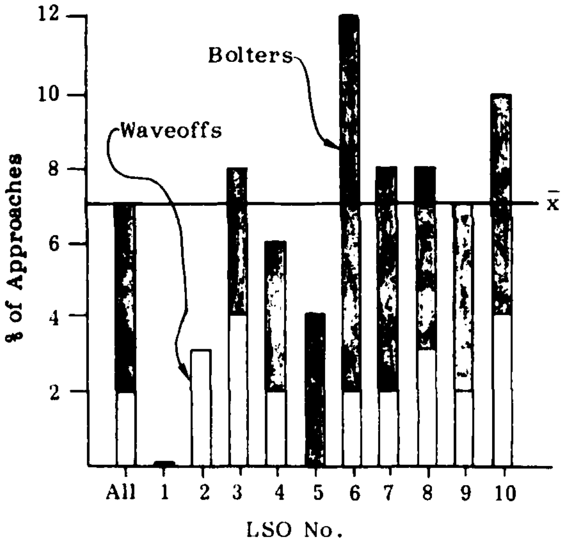

Figure 2. Night Unsuccessful Approaches by LSOs Across All Aircraft Types for Combat Sample.

NIGHT LANDING PERFORMANCE SCORES (LPS). Landing Performance Scores present the first opportunity to assign a composite weight to the quality of overall LSO performance. The LPS is a weighted concensus of the 'goodness' of terminal outcome based on the number 3 target wire. All other landing outcomes have scores relative to that of the target wire.

LSO LPS scores are presented in Figure 3. Overall, LSOs averaged 4.95 for LPS scores across all aircraft. LSOs varied in their LPS scores from 5.31 for LSO number one, to 4.54 for LSO number ten. Most LSOs deviated only slightly from the mean with the exception of the high and low LPS scores of LSOs number one and number ten, respectively.

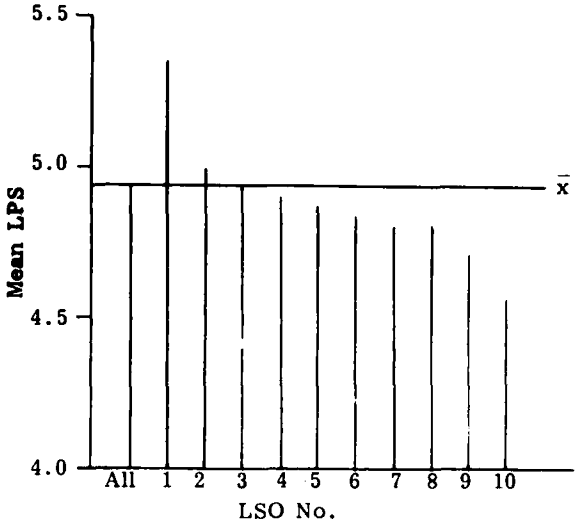

Figure 3. Mean LPS by LSO at Night Across All Aircraft Types for Combat Sample.

FINAL APPROACH OUTCOME PROFILES. LSO final approach outcome profiles present in a composite form all the data previously presented in separate figures. Each column of data presents the boarding rate, LPS, final outcome distribution and a relative graphic portrayal of all outcomes across all LSOs (see Figure 4). The profiles represent a comprehensive method of formatting all LSO performance measures for quick reference, summary, comparison and contrast. This is especially useful in identifying training strengths (number 3 wire) and potential weaknesses (waveoffs, bolters, number 1 wires).

For example, the boarding rate, LPS and wire arrestment frequency data can be obtained quickly and easily by locating the LSO number and then checking that particular column. The average performance for all LSO's shows that the largest percentage of outcomes was on the number three target wire (40 percent) and the fewest was on technique waveoffs (2 percent). The distribution reflects a high number of target wire arrestments, a small percentage of number one wire arrestments (short landings) and a combined 84 percent of all approaches terminating in number 2, 3, or 4 wires. Waveoffs, bolters and number one wire arrestments are minimized (16 percent). Each individual LSO can also be compared to the sample mean as well as with every other LSO. Using LSO

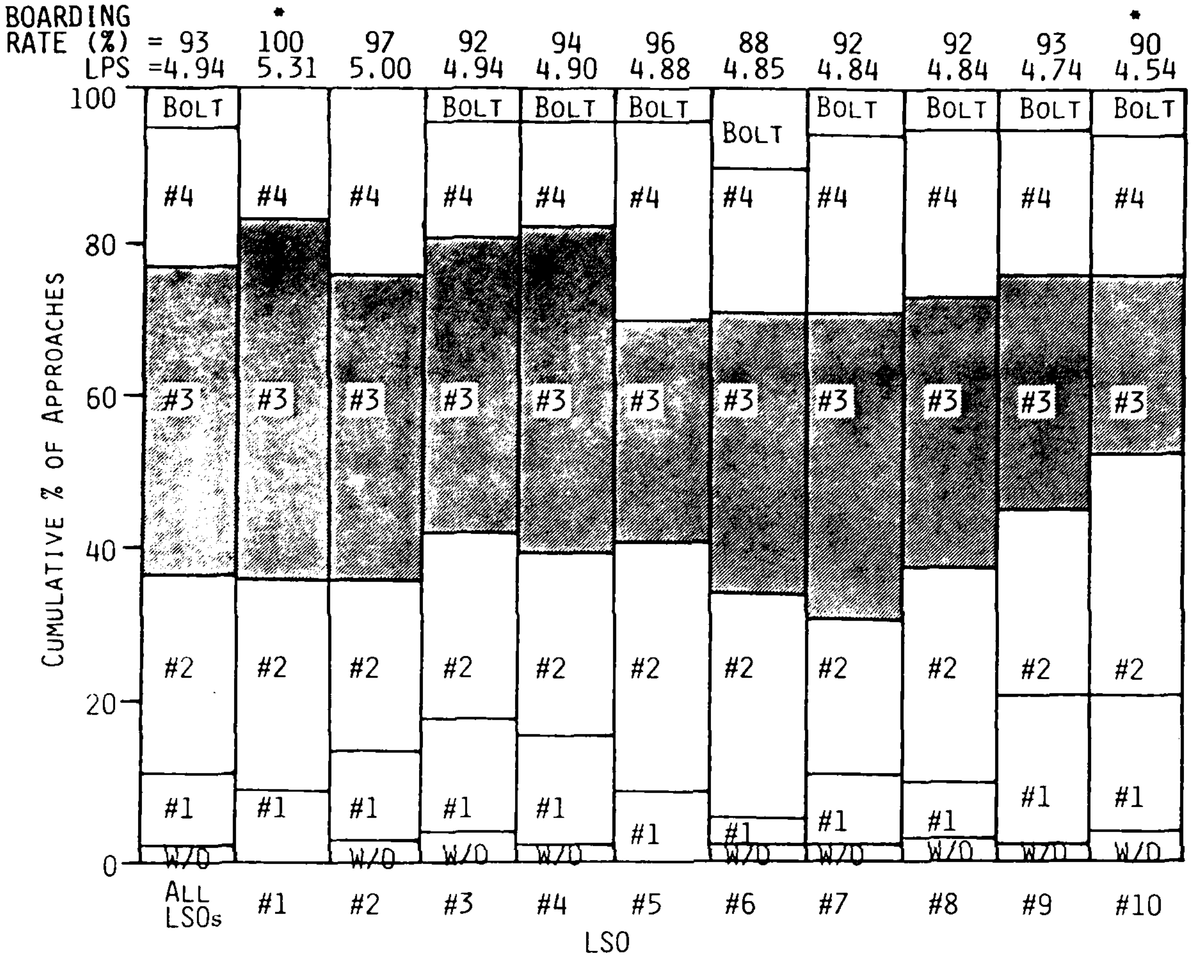

Figure 4. Night Final Approach Outcome Profile by LSO Across All Aircraft Types for Combat Sample.

number one and number ten as examples, their performance differences are readily apparent and the relative differences between and among LSOs are easily identified.

LSO VOICE CALL ANALYSIS. Part of the data collected during the night CQ sample consisted of precision radar records of aircraft final approach parameters and synchronized with LSO voice calls recorded during the actual final approach. These data present the first opportunity to analyze LSO voice calls made to pilots during final approach. The voice calls are for F4 and A7 night CQ operations. A7 CQ data were collected during pitching deck conditions, while F4 data were recorded for normal, high visibility, CQ recoveries.

LSO voice calls are analyzed by the following methods which are intended to provide both descriptive and diagnostic information on the nature of LSO calls, their variability across LSOs and their effectiveness as evaluated by various criteria.

- Frequency of LSO voice calls
- Distribution of calls by aircraft type
- Boarding rate with and without LSO calls
- LSO calls by range interval
- Type of LSO voice calls
- Ambiguous LSO voice calls
- LSO calls by NATOPS taxonomy

FREQUENCY OF LSO VOICE CALLS. The frequency of LSO voice calls made during each night CQ approach for A7 and F4 aircraft were analyzed. Seventy-one percent of all night approaches had one (37%) or two (30%) LSO voice calls, 14 percent had three calls, 10 percent had four or more calls, and five percent had no calls at all.

DISTRIBUTION OF CALLS. The distribution of LSO calls by aircraft type was found to differ for F4 and A7 CQ approaches. The majority of A7 approaches (55 %) had only one call while two calls was the largest category for F4 approaches (46%). Only three percent of all A7 approaches and 20 percent of F4 approaches had four or more LSO calls per approach. This method of portraying LSO voice calls by frequency of calls and percentage of approaches with one or more calls is a useful way to breakdown the LSO call data into more meaningful training feedback information on how frequency of calls varies by aircraft and LSO combinations.

BOARDING RATE. Probably a more operationally useful method to analyze LSO voice calls is to see the effect the number of calls has on boarding rate and LPS by aircraft type. With one or more calls, boarding rate for A7 and F4 CQ approaches was 74 percent and seems to indicate that some LSO feedback enhances successful recovery. When no LSO voice calls were made boarding rate was only 55 percent.

When looked at separately, F4 LSOs averaged 2.3 calls per approach for a boarding rate of 83 percent and an LPS of 4.2. A7 LSOs averaged 1.5 calls per approach for boarding rate of 55 percent and an LPS of 3.3. Recall that A7 recoveries were made during CQ under pitching decks. It seems that fewer LSO calls per approach were made for A7s operating under pitching decks than for F4s operating under normal recovery conditions. Part of the explanation may lie in the philosophy of some LSO CQ training. In order to develop an autonomous pilot, at times LSOs withhold voice calls to encourage pilot self reliance and avoid over dependence on the LSO for approach information. This is especially true under CQ training conditions when the pilot is first learning the skills and judgement to land aboard ship. While this training philosophy may not be consistent across LSOs, it may be one reason why A7 LSOs had fewer calls per approach than did F4 LSOs even though more severe environmental conditions prevailed for the A7 CQ trials. In any case, one point to remember is that the methods used to analyze the LSO voice calls can be used to detect variations in LSO training philosophy and appear to be useful in describing and understanding LSO voice call behaviors.

RANGE INTERVAL. The range interval of LSO calls were delineated into final approach phases --at the start, in the middle, in close and at the ramp. A comparison found that A7 LSOs provided just over 20 percent of their voice calls in the vicinity of the ramp as contrasted to under 10 percent for the F4. Other differences were only slight with a gradual increase in LSO calls as the aircraft nears touchdown. Range interval plots may be useful in depicting variation in aircraft/LSO interactions and providing data to allow determination of a standard range based response set for different aircraft types. In these data it appeared that the A7 LSOs provided equal information all the way to the ramp, while F4 LSOs tended to provide more information early in the approach. These differences are probably due to different aircraft response times. Again, the A7 had pitching decks which may also have contributed to a higher percent of calls made at the ramp.

TYPE OF LSO CALLS. The types of LSO calls were further categorized by: glideslope calls, power calls, attitude calls, ambiguous calls and other calls. LSO F4 voice calls were dominated by power (28 percent) and glideslope calls (28 percent). A7 calls were mostly glideslope calls (51 percent) with only 14 percent power calls. This method of analyzing voice calls seems to indicate its potential for describing variations of LSO calls with aircraft type due to response characteristics. In the example used there are clear differences in the frequency of call types between F4 and A7 aircraft types.

Another interesting category of calls are indicated by what we term "ambiguous" calls.

They represented 16 percent of all F4 calls and 24 percent of all A7 LSO voice calls. An example of an ambiguous call is "Fly the ball." Ambiguous calls require the pilot to decide where he is on the final approach before he responds to the call. The most frequently used ambiguous call was "Fly the ball" which made up 44 percent of all these types of calls.

A brief analysis of ambiguous "Fly the ball" calls revealed that half the calls were made when the aircraft was above glideslope and half when the aircraft was below glideslope. When compared to directional calls such as "Don't go high," ambiguous calls showed a lower boarding rate (67%) and LPS (3.8) compared with a higher boarding rate (75%) and LPS (4.2) for "Don't go high" calls. The tentative conclusion reached is that specific types of LSO voice calls may influence terminal performance, especially the use of ambiguous calls. A sizeable percentage of ambiguous calls were made during CQ training and the methods used to describe the data allows computation of their frequency and effect on terminal performance.

LSO CALLS BY NATOPS TAXONOMY. The LSO NATOPS Manual has four categories of voice calls: informative, precautionary, imperative and non-standard.

The largest percentage of calls for the F4s were imperative calls (54%) and for the A7, non-standard calls (58%). Non-standard calls are those that do not conform to the official NATOPS taxonomy and are somewhat like ambiguous calls, which would be included as non-standard calls in most cases.

Measurement and analysis techniques such as those presented in this analysis of LSO voice calls should prove useful in formulating various LSO training standards for voice transmissions monitoring and assessing their application in fleet and training operations.

LSO CONTROL EFFECTIVENESS

LSO control effectiveness was analyzed using night final approach data recorded by twin precision radars augmented with time synchronized LSO voice calls to the pilot. Three examples of LSO control effectiveness were prepared. One example was a vertical and lateral error plot and LSO voice calls for what is considered to be an effective LSO/pilot interaction. LSO control effectiveness means that the LSO calls were informative, timely and useful in assisting the pilot to a successful number three target wire recovery. Other examples were effective LSO calls, poor pilot response and late LSO calls coupled with good pilot response. The examples were analyzed in detail to provide an indication of how useful radar records with time synchronized LSO voice calls are in analyzing LSO control effectiveness. The synchronized voice and error traces permit us to infer the LSOs perceptual ability and, therefore, to describe his "seaman's eye." The implications of this technique for LSO training, especially simulator training now under development, are enormous in terms of assessing LSO precision and accuracy in night carrier recovery operations and providing diagnostic training feedback for performance enhancement.

ANALYSIS OF LSO TECHNIQUE WAVEOFFS. One useful way of describing LSO effectiveness in the area of safety monitor is to analyze technique waveoffs. For the night CQ sample of 150 F4 and A7 recoveries, there were fifteen LSO technique waveoffs. Ten percent (15) of the night CQ sample consisted of LSO technique waveoffs. Twelve of the 15 were A7 (pitching deck) waveoffs. Sixty percent of the waveoffs were between 300 and 500 feet from touchdown. Seventy-five percent were within 600 feet. At the other extreme, 25 percent were beyond 750 feet from touchdown. When the altitude error of each waveoff was calculated, eight were found to be above glideslope with a mean of 13 feet high and a range of 496 feet from touchdown. Seven were below glideslope with a mean of 9 feet low and a waveoff range of 668 feet from touchdown. From this analysis it appears that low waveoff passes are terminated sooner than high waveoff approaches. Also, the average deviation from glideslope was less for low approaches which are waved off than it was for high approach waveoffs. Thus, it appears the LSO acting as a safety monitor may have different criteria for high and low waveoffs. The promise of empirically identifying the waveoff cluster ranges would allow a more objective determination of LSO waveoff boundaries by aircraft type. Eventually, objective waveoff standards could be developed using this measurement technique.

Another way to describe LSOs effectiveness in monitoring final approaches is by looking at what we describe as satisfactory landings (#2, #3, and #4 wire arrestments), or conversely, unsatisfactory landings (bolters, waveoffs, and #1 wire arrestments). In the absence of accident data, this method could provide some feedback on the central tendency or accuracy of LSO performance in arresting aircraft on the number three target wire. For the combat sample 84 percent of the night approaches were so-called satisfactory landings, and only 16 percent unsatisfactory.

DISCUSSION

LSO performance was analyzed within a carrier landing system framework. Performance measures related to the two primary LSO functions--safe and expeditious recovery of aircraft --were developed and applied to two samples of recovery data. As a safety monitor, the LSO must detect unsafe aircraft deviations from the optimum glideslope and waveoff all approaches that present an imminent danger to the safe recovery of aircraft and crew. As a control monitor, the LSO is expected to expedite recovery by continuously assisting the pilot in the pursuit of a successful, and timely, approach. While these functions are not exclusive of each other we have used different performance measures to describe the relative variability of LSO performance within each functional role.

The most promising feature of the methods presented is their empirical base. While the measures have been derived from information extracted from an existing carrier landing data bank their application to LSO performance measurement was successful in all respects. The use of operational measures such as boarding rate, approach distributions and unsuccessful approaches, as well as research measures represented by the LPS, provide a comprehensive summary of LSO performance in his two functional modes.

The emphasis in this report, however, is placed on the performance measurement techniques rather than the LSO performance data itself. While samples of LSO performance during combat and CQ training were chosen to represent the broad range of LSO activity in carrier recovery operations, the primary intention was to apply and test the measurement techniques and not to assess LSO performance per se. During the course of reviewing the data with staff, fleet and training LSOs it was apparent that some of the performance descriptions were pertinent to current LSO training especially analysis of LSO voice calls and unsuccessful approaches. Several suggestions were also made as to how the data might be used to develop performance standards for various stages of LSO training. For example, LSO performance in the combat sample could be used as preliminary operational standards. The high performance levels attained by the airwing LSOs represents a standard of excellence, or goal for combat deployment. Consider the following performance criterion levels for that data across the two LSO functions.

- <u>LSO Expedite Recovery Function</u>

  Day Boarding Rate: 97%
  Night Boarding Rate: 93%
  LPS: 5.03 Day, 4.95 Night
  Bolters: 2% Day, 5% Night
  % Target Wires: 41% Day, 41% Night

- <u>LSO Safety Monitor Function</u>

  Accidents: Zero
  Technique Waveoffs: 1% Day, 5% Night
  Satisfactory Landings: 87% Day,
  84% Night

LSO carrier landing performance can be assessed using these preliminary standards or similar standards agreed upon as appropriate by command or training personnel. While these data do not represent a consensus as to the desirable levels of LSO performance, data collected across these candidate criteria could provide the information necessary to develop LSO performance standards for combat as well as other operational or training conditions.

The analysis of LSO performance during CQ trials using radar records with time synchronized LSO voice calls is a most promising technique for measuring LSO control effectiveness and for training and performance enhancement. With beginning LSOs the technique appears useful for describing actual final approaches with annotated LSO calls. These records could be used to familiarize the student LSO with correct use of voice calls, the nature of pilot responses, and appropriate final approach corrective actions. Various aircraft approaches and LSO calls could be collected in the fleet for a wide variety of aircraft, weather and environmental conditions. They would provide trainee LSOs with operational examples of experienced LSOs waving aircraft under variable conditions found in the fleet. The measurement technique would also seem invaluable for any LSO simulator training. Additional techniques to measure LSO safety monitor functions include the analysis of technique waveoffs which could prove useful in empirically describing waveoff range data and LSO waveoff boundaries if based on a large enough sample of operational landings.

The analysis of LSO voice calls is a fruitful method to collect data for standards development. The preliminary description of LSO voice calls presented here has raised a few training questions. What is the LSO community concensus on different LSO use of non-standard or ambiguous calls? Also, what types of calls are most appropriate for different aircraft approach conditions? Continued collection and update of LSO performance data would seem mandatory to provide answers to a host of LSO voice call effectiveness questions. The measurement technique is available and the operational and training communities would appear to benefit from its continued development and application.

Finally, some thought should be given to the development and implementation of a carrier landing performance measurement system aboard ship. A manual version of such a system now exists and was used to collect the data presented here. Such a system would provide objective measures of both pilot and LSO performance for day and night carrier recovery. With a shipboard performance measurement system, precision radar data, synchronized with LSO voice calls, could be used for a detailed assessment of LSO performance effectiveness in terms of the prediction and control of aircraft recovery.

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EVALUATION OF THE LSO REVERSE DISPLAY PORTION OF THE A7E NIGHT CARRIER LANDING TRAINER, DEVICE 2F103

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INTRODUCTION

The Navy has recently procured an LSO training station for the A7E Night Carrier Landing Trainer (NCLT). This station is called the LSO Reverse Display (LSORD). It provides a simulated night carrier approach scene, as viewed from the LSO platform, and provisions for "waving" approaches flown by a pilot in the NCLT. An NTEC-sponsored project is underway to evaluate the training effectiveness of the LSO Reverse Display. This paper presents preliminary findings which have resulted from early evaluation activities.

PROJECT OVERVIEW

Several objectives were established in the initial planning of study activities:

- assess effectiveness of the LSO Reverse Display for supporting LSO training
- identify potential enhancements to the LSO Reverse Display
- compare LSO Reverse Display training effectiveness to other device and method alternatives
- delineate guidance for effective utilization of the LSO Reverse Display in terms of syllabus factors and instructor functions
- revise prior estimates of functional performance capabilities needed for an LSO training system as substantiated by research results.

The activities which were planned to support achievement included:

- a limited transfer of training study
- surveys of the LSO community concerning the LSO Reverse Display and alternative LSO training devices and methods
- observation of LSO Reverse Display operation in a training context
- development of syllabii to guide LSO Reverse Display employment in Phase II and Phase III LSO training.

During the period of performance covered by this paper several activities actually occurred. A questionnaire was distributed within the LSO community to elicit initial impressions of the LSO Reverse Display regarding its features and its effective utilization. Project personnel spent time on-site at NAS Lemoore and NAS Cecil Field observing LSO Reverse Display training operations and collecting study data. A syllabus for employment of the LSO Reverse Display in Phase II LSO training was developed. Throughout the reporting period there was extensive interaction with the LSO community. The initial impression resulting from this study is that the LSO Reverse Display shows significant promise for effectively supporting LSO training.

THE LSO REVERSE DISPLAY

The LSO Reverse Display is an LSO training station which has been added to the A7E Night Carrier Landing Trainer (NCLT), Device 2F103. The device is installed at two Navy sites, NAS Lemoore, California, and NAS Cecil Field, Jacksonville, Florida.

The LSO training station is a light-proof and sound-proof enclosure which houses a visual system, an LSO instrument console, normal LSO workstation control items and control units for training station operation. There is a separate instructor station which serves both the LSO Reverse Display and the NCLT. This console contains a single CRT for viewing both the LSO and pilot approach scenes and controls for operating the LSORD.

From the LSO training station (fondly called the "igloo"), the trainee can "wave" simulated night carrier approaches flown by the pilot in the NCLT. The LSO view includes two CRTs with approximately an 80° field of view of the carrier deck and horizon. The wall of the training station enclosure has an extended horizon line which matches that portrayed on the CRTs. The view of an approaching aircraft is maintained within the CRTs throughout the approach (including touchdown and bolter) by a computer driven "scene rotation" process. The visual system can depict carrier deck motion. As the aircraft approaches the carrier, an outline of the aircraft shape gradually appears on the display. Engine sound, as heard from the LSO platform, is provided and is correlated to range and to the pilot's throttle positioning. Background carrier deck noises are also available. For task interaction the trainee has the normal LSO control instruments: radio handset, pickle and MOVLAS. For instructional interaction, there are several elements displayable to the trainee. There is a green crosshair depicting optimum glideslope and lineup, and there is a red crosshair during rerun showing MOVLAS positioning. Alphanumerics which delineate approach results are available at the end of an approach. During rerun, graphic plots of aircraft approach dynamics are available. The trainee has communications with the NCLT pilot and the instructor console, through the radio handset and loudspeaker located in the enclosure. Inside the enclosure are controls for operating many features of the device.

The instructor station at the NCLT console has several means for monitoring an LSO training session including an option for viewing either the LSO or pilot scene. For set-up and control of a training situation he has many options available, some controllable on the console, some through the computer system terminal and some through communicating with the pilot for planned approach deviations. Among his most significant instructional and debrief functions are freeze, approach rerun and control of data to be displayed to the trainee. For "pilotless" LSO training there are ten canned approaches available.

STUDY RESULTS

SURVEY

A questionnaire entitled "Evaluation of LSO Reverse Display" was distributed to approximately 35 LSOs of various skill levels and within various aircraft communities. Only LSOs who had some "hands on" familiarity were included in this distribution. The paragraphs below describe survey results.

SURVEY SAMPLE. Completed questionnaires were received from 17 LSOs. Two LSOs filled out the questionnaire twice, before and after they had some experience with the LSORD. Of the 17 respondents, 16 identified themselves and provided demographic data. One chose to remain anonymous. Five of the LSOs had previous experience with the Night Carrier Landing Trainer (NCLT), while 11 had none. Only 2 of the LSOs had previous experience with the LSORD portion of the NCLT. Therefore, 14 (and possibly 15) of the 17 LSOs were responding to the questionnaire based on limited experience with the Reverse Display. While the LSO sample was limited in prior exposure to the Reverse Display, nearly all had extensive LSO and pilot experience. Six were staff-qualified LSOs, two were TRACOM qualified, one was WING qualified, and four were SQUADRON qualified. Years of experience as an LSO ranged from 1 to 11 in the sample, with a median of 5 years.

LSORD FEATURES RATING. The LSOs were asked to rate some of the training features of the LSORD, as well as the overall potential value of the LSORD for training. Eleven items were rated on a five-point scale, with 1 = POOR, 3 = FAIR, and 5 = OUTSTANDING.

The "degree of realism of the night carrier approach scene from a waving perspective" was given a moderate mean rating of 3.76. Four items received lower mean ratings and six items received higher. None of the LSOs rated the scene realism as OUTSTANDING, but 94% rated it FAIR or better. Only one LSO rated it below FAIR.

The follow-up question on "night carrier approach scene realism" asked about its "adequacy for LSO training." All of the LSOs rated it FAIR or better, and 41% rated it OUTSTANDING. The mean rating was 4.24, the second highest of the eleven items, surpassed only by the "LSORD overall potential value to LSO training" at 4.41.

The "degree of realism of the LSO workstation" received a relatively low rating, although 94% gave it a FAIR or better. No one rated it OUTSTANDING, and one LSO rated it below FAIR. The term "workstation" in the question was general, so it is difficult to judge what aspects of the LSO workstation seemed unrealistic to the LSOs.

The next three questions dealt with the "adequacy for training" of different aspects of the LSORD workstation. The "adequacy of LSO console displays for LSO training" received the lowest mean rating of the eleven items, 3.47. However, there was a wide range of LSO responses. Two LSOs rated it OUTSTANDING, while three rated it below FAIR. Again, it is not possible to determine what aspects of the console displays contributed to the relatively low mean rating.

The "adequacy of LSO controls for LSO training" received the median rating. Five items received higher ratings and five lower. Six LSOs (37%) rated the LSO controls OUTSTANDING. The controls in the LSORD are identical to those used aboard ship, including the LSO hand switch (pickle), radio, and MOVLAS.

The "adequacy of sound simulation for LSO training" was rated FAIR or better by all of the LSOs, although none of them rated it OUTSTANDING.

Two questions were asked about the simulated aircraft dynamics. Their "realism from a waving perspective" received a moderately low rating of 3.65. One LSO rated it below FAIR, but two LSOs rated it OUTSTANDING. By contrast, the "adequacy of the simulated aircraft dynamics for LSO training" received a relatively high mean rating of 4.12.

It is interesting to note that "simulated aircraft dynamics" questions, as well as the "night carrier approach scene" questions, received a relatively low rating for "degree of realism" but a high rating for "adequacy for LSO training." The relationship between simulator fidelity and training effectiveness has been the topic of some debate by training experts. Extrapolating from the LSOs responses to the survey, they appeared to be stating that LSORD departures from "realism" were noticeable, but not expected to detract from LSO training.

The adequacy of LSO trainee evaluation was rated higher for the instructor LSO positioned at the NCLT console than when the instructor was stationed inside the LSORD workstation (the igloo). The reverse display is available at the NCLT console, and the instructor has more controls available for managing the training process. Also, the view of the approach for the second man (the instructor) in the igloo is somewhat awkward because of the limited area for proper head and eye position. A potential disadvantage to the instructor being located at the NCLT console is that communications with the LSO trainee are by ICS rather than face to face.

The final question concerned the "overall potential value of the LSORD to LSO training." This item received the highest mean rating, 4.41. A rating of OUTSTANDING was given by 53% of the LSOs, while 35% rated it GOOD and 12% FAIR. The LSOs apparently felt that the total package was more valuable for training than the individual elements. This overall rating was substantially higher than any other category. Responses to this question may reflect the LSOs desire to receive some training aid, since the primary training method currently is OJT.

UTILIZATION OF THE LSORD. The LSOs were asked which phases of LSO training could be meaningfully supported by the Reverse Display, with the following results: 87% positive for Phase II, Field Carrier Landing Practice (FCLP), and 67% positive for Phase III, Carrier Training Observation. A brief description of these LSO training phases is provided in the LSO NATOPS Manual (Navy, 1975).

When asked to indicate which phase of LSO training would be best suited for the LSORD, 20% indicated Phase I, 40% Phase II, and 40% Phase III. The explanations which accompanied this response emphasized that the LSO trainee who would most benefit from the LSORD would be one who had seen night carrier operations. The LSOs selected one or more levels of LSO experience for which the LSORD would be suitable for supplemental training. The outcome corroborates the results from the previous question. The highest category was "slight experience aboard ship." The second place category was interesting, in that a completely different application of the LSORD was implied — refresher training rather than initial training. The second category was "Wing Qual returning from non-LSO tour of duty."

Another issue in utilization of the LSORD is the level of pilot skill appropriate for flying the NCLT when conducting LSO training. Four categories of pilots were suggested, and the associated percentage of LSOs who favored each was as follows: RAG student pilot, 8%; squadron nugget, 31%; experienced pilot (non-LSO), 15%; and LSO, 46%. When the LSOs were asked to identify their second choice for NCLT pilot, "experienced pilot" was highest with 58%, followed by "squadron nugget" with 25%. These results suggest some scheduling and utilization difficulties for the LSORD. The pilot of last choice for LSO training was the RAG student pilot, but the NCLT is used primarily for training RAG student pilots.

Several items were frequently noted when asked about "system characteristics and/or capabilities...particularly valuable to LSO training." Pitching deck simulation was most frequently noted. MOVLAS and "pickle" time in an adequately simulated night carrier landing environment were also items of significant note.

Several items were frequently noted when asked about needed improvements for LSO training. Overall perceptual difficulties for the "in close" and "at the ramp" portions of the approach, and nose altitude and lineup perception throughout, were most frequently noted. Incorporation of additional aircraft types into the simulation was a frequent suggestion for improving the system.

Notable comments concerning optimum utilization seem to emphasize frequent utilization, use of the device between carrier ops periods (CQ, type training) and utilization by the entire LSO community whenever possible.

LSO PERFORMANCE MEASURES. The LSOs were asked to rate 23 potential measures of LSO performance. The list of candidate measures of LSO performance were not specifically related to the LSORD. The underlying strategy was to allow LSOs to identify reasonable measures of LSO job performance, most of which can be obtained within the NCLT/LSORD system.

Ratings were given on a five-point scale from 1 = definitely not indicative of LSO performance through 5 = definitely indicative. The three highest ratings were for measures which are dependent solely on the LSO and not on a combination of LSO and pilot performance. "Correctness and timeliness of LSO calls" received the highest rating, with 94% of the LSOs surveyed rating it DEFINITELY INDICATIVE. The next two candidate performance measures with highest ratings were "correct recognition of glideslope, lineup, and AOA deviations," and "MOVLAS positioning accuracy."

The remaining 20 items all related to aircraft flight parameters or landing outcome. These variables all are composite of the performance of the pilot, aircraft, and LSO. Therefore, the measures tend to be influenced by the LSO, but not directly controlled by him.

The highest rating for this type of measure was "ramp strike rate," followed by "sink rate at touchdown," "glideslope deviation during the approach," "boarding rate," and "line-up deviations." The lowest ratings were given for measures that most directly relate to pilot technique — "rough nose" and "rough power." These measures were rated, at best, as "possibly indicative" of LSO performance.

A formal definition of the highest rated performance measure, "correctness and timeliness of LSO calls" is currently being developed in another NTEC project by Human Performance Research, Inc. (Borden and McCauley, 1978).

Unfortunately, from the viewpoint of ease of performance measurement, it is the composite (pilot/aircraft/LSO) measures that are easiest to obtain from the NCLT software. "Correctness" of LSO calls currently is a subjective judgment, not amenable to measurement within the NCLT/LSORD system.

OBSERVATION ACTIVITY

On-site observation of LSO Reverse Display operation involved six visits. Four visits were to NAS Lemoore and the other two were to NAS Cecil Field. The first three visits were oriented to familiarization with the features and operation of the system. The last three were oriented to observing the operation of the system in a training context. At NAS Lemoore (two visits) Phase II training was being conducted. Phase III training was being conducted at NAS Cecil Field (one visit). The trainees involved with the LSO Reverse Display had entry levels varying from inexperienced to squadron qualification with night shipboard waving experience. All trainees were from the A7 community except one, who was from the S-3 community. Two LSO instructors were involved. One was from the A7 Fleet Readiness squadron; the other was an Air Wing LSO. Both instructors were very highly skilled LSOs and demonstrated a high degree of motivation and conscientiousness in their instructional duties.

The observation effort also included frequent interrogation of LSO instructors and trainees concerning their impressions of various features, instructor techniques, instructional strategies and conduct of training sessions. Information gathered during observation included frequency of feature utilization, opinions of feature effectiveness, instructor techniques used, procedures followed during training sessions, difficulties in system operation and instructor evaluation of trainee performance.

Although both instructors appeared to perform their duties with equal effectiveness, some interesting differences were noted. One instructor preferred to monitor the LSO view most of the time, the other preferred the pilot view. One used approach results data and approach dynamics rerun plots frequently for helping the trainee learn the perceptual aspects of the task. The other preferred to rely on rerun and frequent freeze for pointing out approach deviations. One placed heavy emphasis on immediate recall of the approach for grading pilot performance. The other focused primarily on the waving of the approach.

SYLLABUS DEVELOPMENT

The initial activity in Phase II syllabus development involved the identification of tasks associated with the conduct of FCLP. The task listing presented in an earlier NTEC report (Hooks et al., 1978), guided this effort. These tasks were then correlated to the syllabus design rationale and the syllabus from that report, as well as the Phase II training guidelines of LSO NATOPS (Navy, 1975). This provided a tentative sequencing of learning activities for the syllabus. The strategy of dividing the syllabus into two learning stages also evolved out of this process. Separate orientations of basic waving skills and pilot refresher training skills enables the trainee to acquire confidence in the perceptual and decision-making aspects of his performance prior to concentration on fine tuning his critique of pilot performance for instructional purposes. This strategy also emphasizes concentrated "hands on" waving experience in the initial stage of learning. A review of the Phase II syllabus, developed by LT Bullard of VA-122, and the information gathered from survey and observation activities provided additional refinements to the sequence. It also guided the final syllabus mix of available media (FCLP, LSO Reverse Display, lecture).

The recommended syllabus provides standardized guidance for learning activity sequencing and the integration of various media. More detailed syllabus guidance does not appear feasible at this time because there will be differences in the learning rates for different LSO task components among trainees. A better understanding of LSO job behaviors, performance criteria and LSO learning processes is required before more specific syllabus guidance can be formulated.

CONCLUSIONS

THE LSO REVERSE DISPLAY

The LSO Reverse Display has demonstrated the potential to be a very effective training device for the A-7 LSO community. As a minimum, simulation of the night carrier landing environment and an approaching A-7 aircraft enables an LSO trainee to perform a considerable portion of the LSO waving task. The highlights of the LSO Reverse Display are simulation of pitching deck conditions and provisions for using the MOVLAS to wave approaches, two aspects of the LSO job which are inadequately addressed in the existing OJT program. Its capability for instructional control of carrier landing situations can provide training benefit to the naive LSO trainee as well as a trainee approaching Wing qualification. It also shows promise as an aid to refresher training for those returning from non-LSO tours of duty.

The LSO Reverse Display does, however, have some limitations of varying significance. One is its obvious orientation and convenient location to the A-7 LSO community, thus minimizing its impact on other Navy LSO training. The requirement for a pilot in the NCLT impacts personnel support for LSO training. There are some operating inefficiencies associated with the conduct of LSO training in the device. There are some perceptual difficulties for the trainee in the final portion of the approach.

The identified limitations do not override the benefits arising from integration of this device into LSO training. The key to its value is effective and conscientious utilization.

LSO REVERSE DISPLAY FEATURES. Some of the more significant conclusions regarding features of the LSO Reverse Display are presented below.

For the student station several items are noteworthy. The carrier approach background scene provides adequate fidelity for training. The clear/foul deck light should be more prominent. Deck motion simulation is an exceptionally valuable feature for LSO training. The A7 visual simulation provides adequate fidelity for training. Frequently there is a convergence problem with aircraft lighting. During scene rotation, aircraft flight dynamics do not maintain fidelity: aircraft looks higher and flatter at the ramp than it actually is; also appears to get smaller than it should. Nose down pitch attitude and lineup are difficult to perceive. Absence of waveoff repeater lights on the LSO instrument console is an irritant to the conduct of training sessions. Audio simulation for the approaching aircraft has adequate fidelity. The controls provided in the student station are adequate for training. The MOVLAS is actual equipment and is one of the most valuable features for LSO training. Crosshair is a valuable cueing aid but trainee must be clearly aware of its proper relationship to the aircraft for optimum approach positioning. Also the trainee must select his own crosshair, a difficult process mentioned later. Crosshair for MOVLAS positioning during rerun is a valuable debriefing aid. Approach results data ("MONITOR") has limited value to LSO trainee due to problem with perception during scene rotation (mentioned earlier) and delaying rerun while data is displayed. Approach dynamics plots ("SCORE") provide useful pilot error analysis data during rerun but value is slightly lessened because of cluttered view of approach. Communications between trainee and instructor through the intercom are frequently garbled. The cause appears to be the acoustic quality of the loudspeaker in the "igloo." Proper eye positioning within available viewing volume is initially difficult to attain. Effective positioning of two heads within the viewing volume is difficult to achieve, thus constraining "over the shoulder" training. Most of the controls for operating system features are enclosed on a pedestal mounting behind the LSO trainee. To activate controls, such as crosshair selection, requires moving from the optimum viewing position, raising the pedestal cover and activating the desired switch (two hands needed). This process is very cumbersome. The cover for station controls must remain closed during approaches because of significant glare generated on the CRT optics by the brightly lighted push-tile switches.

For the instructor station several items are noteworthy. The instructor has adequate information for monitoring training situations and trainee performance through CRT display, notation of control selections, voice communications and aircraft instruments. Placement of controls for changing between pilot and LSO CRT views is inefficiently located at far end of console. The instructor must turn his crosshair off to determine whether trainee has crosshair selected. The instructor cannot monitor MOVLAS positioning at the console during an approach (only during rerun). However, he can monitor meatball positioning in the pilot view and optimum glideslope on the X-Y plotter. The instructor cannot monitor trainee waveoff light activation at the console. The instructor cannot activate the student station crosshair from the console. There are insufficient canned approaches available in the system for meaningful "pilotless" instruction. Rerun of a recorded approach is a valuable training feature of the system. Availability of the MOVLAS positioning crosshair during rerun is a valuable debriefing aid.

LSO REVERSE DISPLAY UTILIZATION. The LSO Reverse Display appears to have the capability to support many levels of LSO training, some levels more significantly than others. If effectively employed, it should decrease calendar time required for LSO skill acquisition and provide significantly more "hands on" experience with more portions of the LSO task than are currently available in OJT. The comments below apply to training in the total LSO community (not just A-7). As mentioned earlier, limited access to the LSO Reverse Display will limit the benefit to LSOs outside the A-7 community.

a. Phase I LSO Training. As a part of the LSO Phase I School curriculum, the LSO Reverse Display could provide instructionally controlled familiarization with the night carrier landing environment and limited "hands on" familiarization with the waving task.

b. Phase II LSO Training. The LSO Reverse Display can enable earlier "hands on" waving experience than is now possible in OJT. It can also enable incremented acquisition of components of the basic waving skill as well as extensive integrated practice. It can also support the learning of pilot grading, diagnosis and debrief skills. MOVLAS and LSO talkdown are Phase II skills for which the LSO Reverse Display is particularly suited. A Phase II training program integrating the use of FCLP and LSO Reverse Display can probably graduate a trainee who is much better prepared for Phase III than was ever possible before.

c. Phase II Syllabus. One of the prime assets of the LSO Reverse Display in support of LSO training is the provision for safe, "hands on" waving experience at the outset of Phase II training. Another prime asset is the instructional control available through such features as freeze, rerun and crosshair. Of the situational features available, MOVLAS and LSO talkdown conditions are particularly appropriate to Phase II training. An effective syllabus can employ these and other features of the Reverse Display, in conjunction with the FCLP environment, to guide the trainee through the completion of Phase II training. The syllabus designed as a part of this project provides a topical sequencing and resource allocation plan for Phase II training. It promotes incremental acquisition of field qualification skills in two stages of orientation, waving and pilot training. The syllabus is of fixed design. Adaptive instructional control, based on learner differences in acquiring LSO skills, can be implemented by the instructor using the Reverse Display for: remedial training sessions, additional practice, and accelerated introduction of new topics during training sessions. It is expected that trainee performance and learning rate while in the Reverse Display will be significantly enhanced if he has observed night operations aboard ship.

d. Phase III LSO Training. The LSO Reverse Display appears best suited to support Phase III training because of its simulation of a considerable portion of the night carrier landing environment. Extensive use of the LSO Reverse Display between CQ and deployment work-up periods looks like the most effective timing of the device in Phase III. The increased waving experience available through the LSO Reverse Display should accelerate skill acquisition. "Hands on" experience with pitching deck, MOVLAS and aircraft emergency situations should produce a more highly skilled Wing qualification LSO than is now possible.

e. Proficiency and Refresher LSO Training. The simulation fidelity appears adequate to support limited maintenance of skill proficiency during extended time periods between deployments. The Reverse Display appears even more promising for its potential to support refresher training for LSOs returning from non-LSO tours of duty.

f. Potential Limitations to LSO Reverse Display Effectiveness. Several factors could limit effectiveness of the LSO Reverse Display in LSO training. Most are not unique to the LSO Reverse Display. A shortage of instructor LSOs can significantly reduce device utilization and effectiveness. Heavy loading of pilot training in the NCLT can limit availability of LSO Reverse Display training time. Limitations in trainee availability for LSO training due to flying duties, school attendance, other job responsibilities, etc., is also a factor. Negative attitudes of instructor, trainee and supervisory personnel toward the LSO Reverse Display can impact its utilization rate and negate its effectiveness. Inattention to quality control of the training syllabus can cause degradation of LSO Reverse Display training effectiveness.

LSO TRAINING SYSTEM CONCEPTS

A critical shortage of skilled LSO continues to plague the Navy. Excessively long training time, reduced carrier operations and pilot retention remain as the primary causal factors. The lower carrier operations activity level experienced by west coast fleet units makes their problem more severe than for east coast units. A recent slowing of airline hiring may result in an easing of retention problems. However, it will probably not have immediate impact on the LSO problem. The long term impact may also be minimal since the duration of the airline hiring slowdown is unpredictable.

The continuation of the LSO shortage confirms the need for measures to accelerate LSO skill acquisition. The promise demonstrated by the LSO Reverse Display confirms the likelihood that a training system (or systems) can help accelerate LSO training and can provide enhanced skill levels for some portions of the LSO task (MOVLAS, pitching deck, etc.).

There appears to be a tightening of travel funds in the Navy. This has a negative impact on accessibility to the LSO Reverse Display by LSOs and trainees not located at NAS Cecil Field and NAS Lemoore. The need for location of training systems convenient to the total LSO community appears even more significant.

Another factor which must continue to be considered is the cost savings which are probable with improved LSO training. If an improvement (such as an LSO training system) prevents one fatal ramp strike accident, there is a multi-million dollar savings to the Navy. Costs of aircraft are in the tens of millions of dollars and the costs of aircrew training are approaching a million dollars. An aircrew fatality may be an even greater loss in view of existing retention problems.

Evaluation of the LSO Reverse Display has provided an opportunity to draw tentative conclusions regarding the LSO training system functional concepts recommended earlier (Hooks et al., 1978). The LSO Reverse Display has functional similarity to the system described in that report with the exceptions of automated adaptive control and performance evaluation. The LSO Reverse Display has shown such promising potential to LSO training, there is strong support for the notion that a universal training system can significantly ease the LSO training problem. The following paragraphs provide discussion of several functional aspects of an LSO training system.

Computer generated imagery for approaching aircraft and background scene simulation appears adequate for training from both fidelity and manipulability perspectives. Field utilization seems to confirm the earlier notion that the night environment is required, but a day scene is of questionable cost-effectiveness. There still appears to be a strong requirement for simulation of multiple aircraft types to satisfy total LSO community training needs. LSO commentary regarding scene rotation problems in the LSO Reverse Display seem to support the need for visual scene field of view coverage of the landing area. The value of the LSO Reverse Display crosshair verifies the need for artificial cueing to aid the trainee in learning to perceive approach parameter variations. Providing scene highlighting and annotation, pilot view of approach and dynamic decision-aiding "zones" appear to be promising instruction effects.

Potential pilot availability problems, instructional presentation efficiency considerations and the potential value of limited instructorless LSO training support the notion of an automated pilot/aircraft ("pilotless" system) capability.

The instructional requirements for wind-over-deck, lens setting, hook-to-ramp and MOVLAS repeater displays still appear strong. The need for a PLAT display now appears controversial except as a workstation fidelity issue. New knowledge that HUD and CLASS are likely to be incorporated into the LSO workstation makes them probable candidates for the training system. The training system would be an excellent vehicle for learning how to use them.

Implementation of pitching deck cues through the visual system alone appears completely adequate for an LSO training system which employs an infinity optics visual system interface. No conclusion can yet be drawn for a large screen projection type of installation.

Automated instructional guidance and evaluative feedback would seem to increase training session efficiency under instructor control, and would be necessary for an "instructorless" mode of system utilization (which looks promising in view of LSO job loading and LSO shortages).

The cost-effectiveness of sophisticated automated, adaptive control remains unknown without a better understanding of the feasibility of modelling LSO job behavior and learning processes. However, evaluation of the LSO Reverse Display has shed some light on limited levels of automated adaptive control and instructor interface functions. Limited adaptive control automation for task and strategy selection within a prescribed syllabus could be initiated through manual performance evaluation inputs from the instructor. This could alleviate some set-up and instructional decision loading on the instructor and improve training session efficiency.

The LSO community feels that evaluation and instructor control of learning situations are best accomplished through instructor judgment. A promising automated control application might be focused on critical waving situations for which performance criteria could be well-defined. A data collection and storage subsystem of student task performance and scenario experience data could provide the basis for subsequent development of a sophisticated and effective adaptive logic.

The need for co-location of the instructor with the trainee appears to have lessened, based on LSO Reverse Display evaluation results. Subjective evaluation appears very adequately supported by monitoring of pilot and LSO views, voice communications and trainee control activations. Uncertainty regarding display of objective performance evaluation support data (to the instructor) continues because of the lack of an objective performance evaluation method. Automation support to the instructor for scenario set-up would help training session conduct efficiency. It could effectively support trainee utilization of the system in "instructorless" situations.

As mentioned earlier, little has yet been learned concerning the implementation of automated performance evaluation support. The correctness and timeliness of LSO calls and control activations continue to be supported as the key elements of LSO performance quality. Reliable modelling of these elements and other candidate indicators for evaluation purposes remains uncertain, except possibly in the case of well-defined, critical situations as mentioned earlier.

PROTOTYPE AUTOMATED LSO TRAINING SYSTEM

As discussed earlier, some uncertainty still remains concerning the functional characteristics of an automated LSO training system. However, it appears that there will be sufficient information available from NTEC-sponsored projects during 1980 to proceed with the development of a prototype system. The need for timely aid to the LSO training problem is another important consideration. Attempts to empirically resolve all system design uncertainty would result in excessive delays. A prototype system could serve as both an operational training system *and* an experimental tool to provide more *definitive* guidance for the characteristics of future LSO training systems.

RECOMMENDATIONS

LSO REVERSE DISPLAY FEATURES

Recommendations for enhancement of LSO Reverse Display features are separated into two groupings: modifications which appear to be relatively simple and/or inexpensive, and those which appear complex and/or require significant analytical attention.

SIMPLE ENHANCEMENTS. The most promising *improvement to the* system would be incorporation of a capability of storing and presenting a larger number of canned approaches. The red MOVLAS positioning crosshair should be optionally displayable in real-time (during an original approach) at both the instructor and trainee stations. There should also be an indication of trainee waveoff light activation at both the instructor and trainee stations. The clear/foul deck light should be more prominent on the CRT display. The sound quality of the intercom system should be improved. There should be control and display of trainee crosshair selection at the instructor console. The pilot view of the approach should be optionally available for display at the trainee station.

COMPLEX ENHANCEMENTS. There are two very significant items which *require* attention. One is investigation and *solution* of the perceptual difficulties associated with the final portion of the approach ("in close," "at the ramp" and during scene rotation). The other is the difficulty in perceiving nose down attitudes during the approach. An investigation should be made into the modification of PMS to provide LSO performance evaluation support. Automation of pilot and aircraft dynamics (providing a "pilotless" training capability) is very worthy of attention. Simulation and display of additional aircraft types is also worthy of attention. Implementation of automated trainee performance evaluation, based on correctness and timeliness of voice calls and control activations appears worthy of attention.

LSO REVERSE DISPLAY UTILIZATION

Recommendations for LSO Reverse Display utilization are oriented toward confirmation of the preliminary study conclusions presented earlier. As a basis for confirmation, the LSO community must take advantage of every opportunity to exercise the LSO Reverse Display in training. Currently, there is an insufficient sample of the LSO community with any significant experience at using the device. If future studies are to be fruitful, this sample must be expanded.

It is recommended that the Phase II LSO training syllabus developed in this project receive timely review by the LSO community and that this syllabus, or modifications of it, be implemented by appropriate supervisory LSOs (most likely air wing LSOs). The sooner this occurs, the sooner the LSO community can receive the benefits of formalized Phase II training and the sooner the syllabus can be evaluated in an operational context.

During utilization of the LSO Reverse Display particular attention should be paid to effective employment of the various features of the device. The conclusions presented earlier provide a baseline for feature utilization. However, extensive exercise of the device should stimulate additional commentary concerning better instructional techniques and device operation procedures.

LSO TRAINING SYSTEM CONCEPTS

The promise demonstrated by the LSO Reverse Display is sufficient to warrant a recommendation for procurement of an experimental prototype automated LSO training system. This system should have characteristics suitable to training within the total LSO community and should have the capability to collect LSO performance data. The design of this system should obviously be based on the final results of this and other related NTEC projects. Special attention should be given to the selection of visual subsystem capabilities, in view of the visual perception problems observed in the LSO Reverse Display.

SUMMARY

Procurement of the LSO Reverse Display has provided two significant benefits to the LSO community. Firstly, it provides LSO training support to LSOs in the A7 community. Secondly, it has provided an opportunity for field evaluation of promising automated LSO training system concepts. Both benefits are likely to support the easing of LSO training problems. The A7 community has already started realizing its benefits in the upgrading of its LSO training program. In the near future, the Navy should be able to utilize the results of this study to support decisions concerning the procurement of future LSO training systems.

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IMPLEMENTATION AND TEST OF A LABORATORY LSO TRAINING SYSTEM

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INTRODUCTION

The Navy's Landing Signal Officer (LSO) plays a critical role in the safety and effectiveness of carrier operations. There currently exists a shortage of skilled LSO personnel that approaches the crisis level. Aggravating the problem is the fact that it takes a long time for the existing training program to develop an LSO to a productive skill level. The Human Factors Laboratory of NTEC is sponsoring research efforts pointed toward determining measures which can cost-effectively reduce LSO training time. One such effort, which is currently underway, is to develop a laboratory LSO training system for research into the application of automated training concepts to LSO training. This system has been through one implementation and testing iteration and is currently under revision based on initial test results. This paper describes the implementation and testing of that system.

SYSTEM DESIGN

The basis for design of a laboratory LSO training system was an LSO training system requirements study (Hooks, Butler, Gullen and Petersen, 1978) sponsored by NTEC. This study examined the LSO job and the existing LSO training program to identify problems and candidate solutions. An automated training system concept emerged as a very promising and potentially cost-effective aid to LSO training. The implication was analogous to synthetic pilot training: an instructionally controlled environment, independent of costly carrier operations, for promoting the acquisition of basic waving skills and for exercise of these skills in critical operational situations, without jeopardizing safety considerations. Other study results included the identification of LSO tasks and learning objectives, development of a syllabus for skill acquisition, delineation of candidate functions for an automated LSO training system and an examination of the status of training system technologies which were relevant to the candidate functions.

The functional architecture of an automated LSO training system supported the identification of key system feasibility issues. One overall issue concerned the feasibility of automating LSO task interaction through the integration of graphics, aircraft dynamics modelling and automated speech recognition. This issue appeared very appropriate to investigation in the laboratory environment. Another issue appropriate to laboratory investigation was the feasibility of automated LSO performance measurement. The relevance of this issue was enhanced by the fact that another NTEC sponsored activity was underway to define the behavioral aspects of the LSO waving task (Borden and McCauley, 1978). Development of a laboratory LSO training system also had the potential to support investigations of instructional features as well as alternative strategies and techniques for promoting the effective acquisition of LSO decision-making skills. These considerations resulted in the initial design of a laboratory LSO training system to be implemented in computer facilities at the Human Factors Laboratory of NTEC.

The primary elements of the laboratory LSO training system include graphic display of the carrier approach scene, a model of pilot and aircraft approach dynamics, automated speech recognition, behavior model based performance evaluation, scenario based exercise control and exercise data recording. The primary hardware components employed include a Megatek 5000 random scan display, a NOVA 1200 CPU, a NOVA 800 CPU with floating point and a VIP 100 voice recognition preprocessor.

The detailed design was a joint effort between Logicon and NTEC personnel. Logicon designed the software for the NOVA 800 CPU which included the graphics, exercise control, performance evaluation and data recording elements. NTEC personnel were responsible for the pilot/aircraft model and speech recognition elements which were to be performed in the NOVA 1200 CPU. The design effort involved frequent interaction among training analysis, LSO subject matter expert and programming personnel. Training analysis and subject matter expert inputs to the design included:

- parameters for scenario control
- LSO vocabulary requirements
- instructional prompting and aiding
- exercise data recording requirements
- performance evaluation criteria
- "pilot" control variations
- instructional scenario definition
- LSO/pilot interaction contingencies.

SYSTEM IMPLEMENTATION

The operating concept for the training system was to allow the subject to view a graphic portrayal of the approach, perceive the need for a voice call and input a voice call through the speech recognition element of the system. The system would then process this call, simulate and display the pilot response and record an evaluation of the subject's performance. Thus the system would provide closed-loop LSO and pilot interaction in an instructional scenario controlled environment.

The hardware available for system implementation was limited in capacity for handling the desired functional capabilities. Therefore several design simplifications were required. For control of aircraft dynamics, the approach was segmented into a limited number of "zones" defining variations in glideslope, lineup and angle of attack (AOA) which are oriented about the optimum parameters for these dimensions. The closing approach speed of the aircraft was fixed at 110 knots. Fixed variations in sink rate and drift rate were also established. These simplifications allow fairly comprehensive scenario control using minimal CPU resources.

The performance evaluation function was also simplified. The behavioral model developed under another NTEC sponsored effort (Borden and McCauley, 1978) was too complex for available CPU resources. Therefore, an evaluation model was devised which was based on the correctness and timeliness of ten basic LSO phrases and the general criteria for their relevance. To minimize complexity, the aircraft state parameters used to establish these criteria only included glideslope and lineup position, AOA, and range segment (start, in the middle, in close, at the ramp). It is essentially a "snapshot" model since rates of aircraft parameter changes (sink and drift rate) are not accountable. However, the model implementation is such that it can be increased in complexity if additional CPU resources become available (as in the case of implementing the system in higher capacity computer hardware). Another limitation of this element is that it does not look for errors of omission (e.g. no call made when one is required). Although simplified, this mechanization still provides an adequate representation of an automated performance evaluation capability for LSO training research.

The aircraft image displayed has minimal fidelity, looking somewhat like a paper airplane. This significantly minimizes graphics processing requirements.

The results of LSO/pilot interaction were also simplified. A correct call by the LSO results in a maneuver by the pilot to put the aircraft in an optimum state (correct glideslope, lineup, AOA). An incorrect call by the LSO is "ignored" by the pilot.

To provide supplemental perceptual aiding to the subject, an aircraft positioning grid was incorporated into the graphic scene. This grid provides a graphic indication of aircraft position relative to the glideslope and lineup "zones" and range segments. Display of this grid during an approach is a pre-selectable option for the system operator (instructor). Another pre-selection option that was incorporated, is a text message that provides scenario generated prompting and real-time performance evaluation feedback. The real-time feedback text displays the phrase recognized by the system and the correct phrase (if different) as determined by performance evaluation.

Scenarios implemented into the system are preprogrammed approach profiles which are keyed to the instruction of the decision-making situations imbedded in the performance evaluation model. Scenario commands provide for aircraft maneuvers within the approach segmentation concept described earlier. They also provide pre-determined textual prompting of voice calls appropriate to the decision situation presented.

From an overall viewpoint, the laboratory LSO training system is a limited representation of all the major functional elements of an automated LSO training system, with the exception of automated, adaptive syllabus control.

SYSTEM TESTING

After implementation, the system was demonstrated to fleet LSOs and an informal test was conducted in-house at Logicon. Two subjects were used in the test, each having a Navy carrier pilot background, but no LSO experience. Over two days, each subject was sequenced through exercises representative of a syllabus based on incremental acquisition of waving skill components (glideslope, lineup, AOA and waveoff related calls). From the standpoint of system operability, the system tested successfully. From a training standpoint, however, several deficiencies were discovered.

One of the major discrepancies involved difficulties on the perception of approach deviations presented by the scenarios. This led to a conclusion that some amount of parameter exaggeration was required to enable meaningful presentation of waving situations.

Absence of a capability to detect errors of omission significantly lessened the value of the performance evaluation function.

It became evident during testing that a freeze capability was necessary for effective conduct of a training session.

The aircraft position grid proved to be excessively cluttered, thus lessening its effectiveness as a perception aid.

The fact that the aircraft responded only to correct LSO calls turned out to be an excessive departure from real-world LSO waving interaction.

There were speech recognition difficulties which were attributed to lack of a contextual voice data collection effort. This capability was implemented at NTEC but was not used in Logicon's in-house testing.

It was noted that the performance evaluation feedback feature would have been more effective if clarifying information could have accompanied the display of the correct call.

Design of the glideslope and lineup "zones" to converge at the optimum touchdown position significantly degraded the depiction of deviations for the "in close" and "at the ramp" segments of the approach. It also precluded allowing the results of the approach to vary. The system was thus unable to provide additional feedback on the effectiveness of LSO control in the terminal portion of the approach.

There was some question regarding the fidelity of the aircraft image from a training standpoint.

It was also noted that some form of evaluative feedback should be presented to the subject by the system following the approach in order to enhance learning rate.

Another result of testing and demonstration of the system to skilled LSOs was the realization that the laboratory system, with refinement, has significant potential as an introductory, part-task LSO decision training system. It could provide limited "hands on" training for a naive trainee in an instructional setting such as the LSO Phase I School.

SYSTEM REVISION

In response to the demonstration and testing results described above, the laboratory LSO training system is currently undergoing revision. Several objectives have been established to guide software revision and research utilization of the revised system.

The first objective is to enhance the system in response to the "lessons learned" earlier in the project. One orientation to the enhancement is to improve the perceptual characteristics of the instructional presentation. This is necessary to minimize the instructional emphasis on learning the perceptual aspects of the LSO decision task and to enhance LSO acceptance of the system as a potential training system concept. The other orientation is toward improved instructional features to support LSO decision learning.

A second objective is to evaluate the effectiveness of providing "hands on" decision-oriented training in the early stage of the LSO learning process. The current LSO training philosophy employs a passive, observational strategy which focuses on the perceptual aspects of the LSO tasks. Early "hands on" instruction should promote a clearer understanding of the relationships between task stimuli and the LSO decision process and should enable the trainee to be more intellectually active in the observational stage of training aboard ship. These factors have significant potential for accelerating skill acquisition in Phase III training aboard ship.

A third objective is to evaluate the feasibility of providing some limited levels of instructorless training to LSOs. The factors in this feasibility investigation are training effectiveness and user (LSO) acceptance. Instructorless training, even for small portions of LSO training, can provide significant benefit in view of existing and forecasted instructor LSO shortages. Although the system will not be totally instructorless, the automated performance feedback features will support investigation of instructorless training concepts. In conjunction with this objective, it is anticipated that some beneficial knowledge will be gained concerning effective methods and content of performance feedback for an LSO training system.

The final objective planned for this effort involves evaluating the utility of a simplified LSO decision-making model to early LSO training. The LSO decision-making process is extremely complex and difficult to verbalize. These factors are largely responsible for the lengthy LSO training process. Over time, the trainee, through extensive observation of skilled LSOs, acquires knowledge of the decision process. Providing the trainee with simplified, but increasingly complex, models of the decision process should promote more efficient acquisition of LSO decision-making skills. This system provides a simplified LSO decision model as the basis of its performance evaluation capability.

There is also an underlying, secondary objective within this project. Since the system itself has potential as a cost-effective automated "part task" training system for the initial stage of LSO training, this possibility will be assessed informally during experimental activities.

To meet these objectives several functional revisions are currently planned. The revisions are delineated below:

Freeze
- operator initiated in run-time
- also, possibly "freeze on error"

Feedback Messages
- in expanded text area
- information on call recognized, correct call, relevant approach parameters
- available during approach
- selectable during freeze

Detection of "Missed Calls" by Performance Evaluation

Graphics Improvements
- "ladder line" to be added to deck scene
- display of improved aircraft image during freeze
- improved perception aid similar to LSO HUD

End of Run Feedback Data on Megatek
- approach result (wire, lineup)

Aircraft Response to Incorrect Calls
- response to incorrect calls which are considered imperative (power, waveoff, right/left for lineup)

End of Run Data to Operator CRT and Student Records
- "snapshot" data for each call and error occurrence during approach
- approach results

Revision of Glideslope and Lineup Zone Origin
- to enable discrimination in approach parameters on touchdown (wires, lineup)

Exaggeration of Lineup, Glideslope and AOA Deviations
- to enhance student perception of deviations

Data-Driven Prompting During Approach
- same text area and format as feedback messages
- scenario driven prompting to be deleted

The design and implementation of these revisions is currently in progress. After the completion of this revision process, a pilot study will be conducted at Logicon to verify system operability and to informally address the issues described in the objectives presented earlier. The pilot study will also support the design of formal experimentation to be conducted at the NTEC Human Factors Laboratory.

SUMMARY

The critical shortage of skilled LSOs continues to plague the Navy. This research effort, employing a laboratory LSO training system, is exploring means for accelerating the acquisition of LSO skills. The early indications from this and other NTEC-sponsored efforts are encouraging, thanks to the cooperative interaction among government and industry researchers and fleet LSOs. Advanced training technologies appear to hold great promise for helping solve the LSO training problem.

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INSTRUCTOR MODEL CHARACTERISTICS FOR THE LSO - THE BRIDGE BETWEEN 6.1 and 6.2

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INTRODUCTION

The present paper is an adaptation of a somewhat larger report entitled "Instructor Model Characteristics for Automated Speech Technology" by Chatfield, Marshall, and Gidcumb which will be available soon. In this larger report, the task requirements of the Landing Signal Officer (LSO) were reviewed along with those of the air-intercept controller (AIC) and the ground-controlled approach controller (GCA) in terms of recent developments in the 6.1 or basic research literature. The present paper is an attempt to review some of the more important concepts which could lead to an instructor model for the development of LSO training systems.

At the outset, it would be good to establish what we have in mind when we refer to an instructor model. Imagine for a moment the characteristics of a human instructor:
1) He possesses a knowledge base which he ultimately transmits to the students,
2) He attends to various performance indeces to gauge student progress,
3) He possesses a set of training techniques which he invokes in the training process,
4) He possesses an ability to self evaluate and modify these training techniques as he gains experience with increasing numbers of students,
5) He possesses a high degree of flexibility in that he can make real-time decisions regarding instructional alternatives throughout the training session. He is capable of using individual student performance indeces as feedback in a closed-loop system. With these characteristics we would then label the human instructor as an intelligent training system.

Current trends in research on automated instruction are moving in the direction of what is called "intelligent knowledge-based training systems." In other words, training systems are beginning to emulate and model the flexibility of the human instructor. This is in contrast to the more rigid "script-based" systems in which training exercises, frames, etc., have been preprogrammed and the control logic of the system is restricted to the control of essentially a branching process.

What we seek is a control logic in a training system which can emulate as many characteristics of the human instructor as possible. This we would refer to as the instructor model. It would possess: 1) a knowledge or skills representation system from which instructional and training exercises could be generated 2) a model of the student which would describe the processes by which a student learns and would summarize a student's current learning state, 3) a generative logic which could generate instructional scenarios and exercises that would optimize marginal increments in learning given a student's current learning state, and 4) processes by which the control logic might modify itself to increase its efficiency as it gains experience with increasing numbers of students. It is these 4 characteristics of the instructor model which we will briefly attempt to address.

CURRENT THEORY ON COMPLEX COGNITIVE TASKS.

Before looking at a knowledge representation system, we need to characterize the skills required by the LSO. Similar to other speech-based training tasks, the LSO's job is a series of complex event-driven cognitive tasks. The LSO must process complex visual and auditory inputs, make real-time decisions, and produce complex verbal responses. He must be able to encode subtle visual cues and process heavy information loads under pressure and at a rate dictated by external events.

A major difference between the expert and the novice is that the expert seems to be able to simultaneously handle multiple inputs, hold information in memory, process the information, and select the next response concurrent with the execution of the present verbal response. The novice, on the other hand, seems to be analogous to the person who can't walk and chew gum at the same time. The novice seems to be held back by a limited central processing capacity.

The basic research literature has proposed several resource competition models based on the assumption of a limited central processing capacity. One view (Kahneman, 1973) describes these limited resources as a pool of "effort" which may be allocated among tasks. To increase performance on a particular task, an individual would need to increases his allocation of cognitive resources to that task. If he was engaged in a second concurrent task at the time, and was already using all of his resources, then he must necessarily borrow some resources from the second task to invest in the first. Thus to produce an increase in performance on one task, performance on a second task may have to suffer.

Norman and Bobrow (1975) have proposed a resource competition model which could be incorporated into the control logic of our instructor model. In their view, whenever the performance on a task can be increased with an increased allocation of resources (e.g. processing effort or concentration) then the task was said to be resource-limited. Whenever the performance level remains invariant to increased allocations of processing effort (resources), the task is said to be data-limited. Here the performance is limited by either poor signal quality (e.g. low signal-to-noise ratio) which was referred to as signal data limits or an inadequately stored memory representation referred to as memory data limits.

Norman and Bobrow describe what they refer to as a resource allocation function in which task performance is related to a single hypothetical dimension of resource allocation. Figure 1 shows resource allocation functions for two tasks. As additional resources are allocated moving from point A to point B on the abscissa, performance increases on both tasks and are resource limited at all points in that range. But as the allocation is further increased from points B to C, no further increase in task I is produced, thus task I is now data-limited while task II is still resource limited.

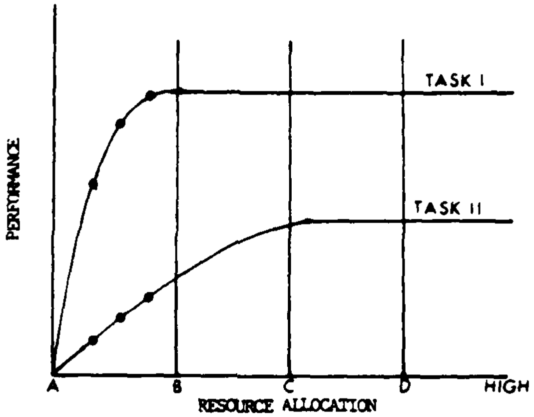

Figure 1. Two example resource allocation functions.

Resource allocation functions are largely hypothetical, but the performance of one task can and has been empirically related to the performance of another task. The left panel of Figure 2 shows such a function between two tasks and is referred to as a Performance Operating Characteristic (POC). The corresponding resource allocation function in the right-most panel shows that the region of investigation on the abscissa is limited to the A to B region referring back to Figure 1. As can be seen, as

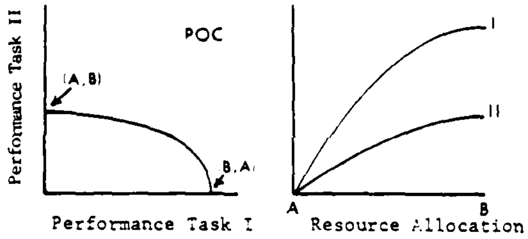

Figure 2. Resource allocation functions and the corresponding POC.

resources are taken from one task and applied to the other, the performance on the first task drops while the performance on the second increases. This would be a typical POC wherein both tasks are resource limited.

One may ask--How then may we account for the fact that the expert controller seems quite facile with concurrent inputs and responses? The expert describes his responses as being quite automatic in nature, requiring little or no conscious processing effort. Norman and Bobrow explain that with practice, the students may learn to become more efficient in their processing, maybe by eliminating processing steps or learning to process the minimum relevant data, etc. Thus with learning, the student approaches his data-limited asymptote more rapidly as he increases his resource allocations. This is depicted in Figure 3.

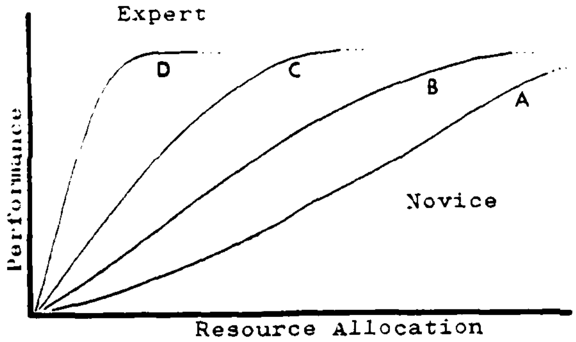

Figure 3. Changes in the resource allocation functions in various stages of training _A_ through _D_.

With a resource function as is shown in function _D_, the expert performing this task would seem to be able to do so independently of other tasks in that with very little processing effort, he achieves data-limitation status. Thus as described here, the performance on this task may not really be "automatic" but simply "cheap" in terms of the amount of resources required to reach asymptote.

The concept of task performance being a function of resource allocation can be extended to the task of learning itself. All of us have observed a human instructor training a student in a complex task telling the student to "concentrate" on certain parts of the task at various points in training. The assumption implied in making the student concentrate on one part of the task at the expense of others is that learning rate is positively related to the amount of resources invested (e.g. concentration). This assumption would then suggest the concept of a resource allocation-acquisition function as shown in Figure 4. As can be seen, the momentary learning rate is portrayed hypothetically as a function of the amount of resources allocated. In this view, the rate at which a task is mastered could be altered by manipulating the resources allocated.

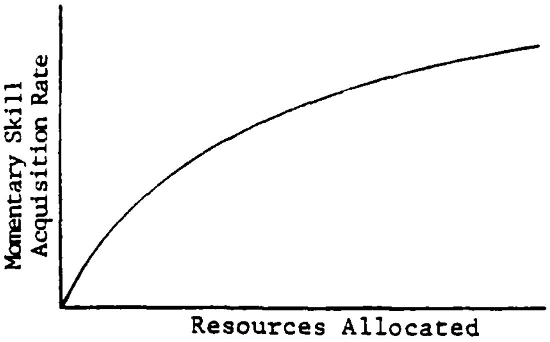

Figure 4. Exemplar resource allocation-acquisition function.

Thus in the training of an LSO, a complex aggregation of seemingly concurrent tasks, the control logic of the system should be able to make real-time adjustments and instructional decisions regarding the demands of the task, such that the novice possesses enough surplus resources to invest in the "learning of a new part of the task." The details of how this could be done are described more fully in Chatfield, et.al. (1979) and Norman (1978). Briefly what is being described is the adaptive training function of the system.

Consider the complex aggregation of tasks such as required of the LSO as being decomposed into various subtasks and parts for training purposes.

The adaptive functions of the system would then control the subtask presentation schedule. As a student is working on a particular portion of the task, the system would not add new subtasks to the composite until the current portion of the task became resource efficient, i.e., the resource allocation function were surmised to look something like function D in Figure 3. If the new subtask were to be added too early, and the resource allocation function of the current composite of tasks was that of A in Figure 3, then the addition of the new subtask would have one of two effects. If the student invested some of his limited resources in the new subtask, his current performance level on the current tasks would fall. If on the other hand, he chose to maintain his current performance levels, he may have to virtually ignore the demands of the new subtask until the tasks on which he is currently working become more "automatic" thereby releasing precious resources. The actual technology of how an intelligent system might solve for the "optimal" point in training at which a new subtask might be scheduled cannot be discussed here, but some may want to refer to Chatfield and Gidcumb (1977) or Chant and Atkinson (1973) for the mathematics and theory involved.

In addition to the example on task scheduling, there are several other ways for the adaptive function of the system to adjust the demands of the tasks during training. The main point to be discussed here however, is the idea that the adaptive logic in the system should be based on the theory on resource limitations currently available in the 6.1 and basic research literature.

In addition to an adaptive function, the instructor model of an intelligent system would incorporate a tutorial function. By the tutorial function, we mean the establishment of knowledge structures, the imparting of facts or rules of behavior by the system. As an example, say that a student makes an incorrect advisory on an approach. The error may have two different causes. One is that the student may have known what the correct advisory should have been, but got confused and committed the error when "two many things happened at once" or in other words, processing demands were too great. Here we would say that the student was resource limited. Presumably, if the approach were repeated with fewer concurrent events demanding some of his resources, he would be able to devote more of his resources to the advisory in question and would not make the error. However, if the demands of the task were decreased and the student still made an incorrect advisory, then we would infer that the error was due to a second cause. It may be that the student had forgotten certain rules on the generation of advisories, or maybe he had never known them. Now his performance is data limited or what Norman referred to as memory-data-limited. The idea here is that no matter how much of his resources the student may invest, performance will not improve with increased resource allocations. Thus the system would need to enter its tutorial function. Here the system might interrupt the continuous approaches of simulated aircraft and simply explain the needed rules for the advisory in question. This would be analogous to a human instructor stopping the practice session for a bit of verbal instruction.

The idea that a training system would alternate between tutorial and adaptive functions rests on the assumption of a process vs. structure distinction currently found in the literature. Structure refers to units of knowledge or schemata, whereas process refers to the activation of the schemata or the utilization of the units of knowledge in processing incoming stimuli for eventual response production. Structure is established through more didactic types of instruction, whereas process becomes more automatic or resource efficient through practice. One of the requirements of the system would be the capability to vary task demands in diagnosing errors as being caused by either processing or structural limitations.

KNOWLEDGE-BASED GENERATIVE SYSTEMS

Recent research in training systems funded by the Office of Naval Research (ONR) has progressed to what is referred to as knowledge-based generative systems (see Wescourt, et.al., 1977). The term "generative" is used in a way to depict the systems capability to generate its own questions and exercises for the students rather than being limited to a preprogrammed series of CAI-style frames. Further, the system may even be able to support student initiative, i.e., questions from the students wherein unique answers are generated by the system (see Carbonell, 1970). To be able to generate and formulate questions and answers, the system must possess the same knowledge-base that the student is to acquire. Currently ONR is funding projects investigating the representation of knowledge, and ultimately how the representation might be used in an automated training system.

Most of the recent work can be described as an incorporation of artificial intelligence in automated instruction. Much of the work however, has centered around the representation of structure and may be somewhat limited in the representation of process. As an example, Goldstein (1979) presents what he calls a "genetic graph" to represent knowledge. The idea of the genetic graph is that it attempts to capture the evolutionary process by which a mature set of procedures evolve. In Figure 5 it can be seen that the nodes representing the rules are linked by relationships of evolution. In the example, all the rules shown evolve from rule A which was learned initially. Rule AB is said to be a refinement of rule A while rule ABC is a version that is refined still further. Rules ADD, AdD, and adD can be viewed as more general (or more specific) versions of rule AD, and are analogous to each other. One advantage of the genetic graph is that it represents the student's knowledge at various stages.

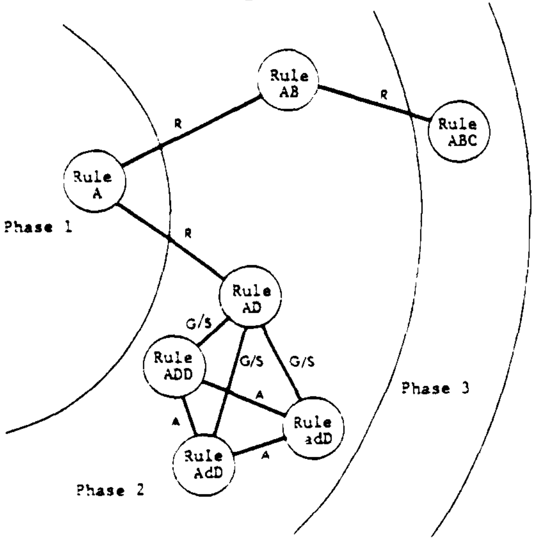

Figure 5. A portion of a genetic graph showing genetic links of refinement (R) generalization/specification (G/S) and analogy (A).

A second advantage is that it provides the system with a means by which it can present new information in terms of previously learned rules. Take for example rule ADD in Figure 5. This rule could be presented to the student as a generalization of rule AD, as being analogous to rule adD or being analogous to rule AdD providing that these other rules were already known. Thus the genetic graph provides the potential for a very powerful means by which the system can make use of prior knowledge in generating multiple styles by which a rule could be presented. Thus if a system can generate tasks, questions or responses to student queries from an appropriately represented knowledge domain, it can possess the flexibility required to provide truly individualized instruction as would a human tutor.

The research on competition for central resources however, points out an important need. The adaptive logic of an automated speech-based training system will need to be involved in resource budgeting during the training of complex concurrent tasks. Let us assume a simple network of tasks which represent those relationships as shown in Figure 6. Let us further assume for illustration that we could quantify task demand for central resources as a percentage figure, both for tasks executed in isolation and concurrently.

As can be seen in Figure 6, tasks B and C are represented as independent tasks. If truly independent, then presumably the student could be required to perform at both tasks without both of them competing for the same central resources. Tasks A and B however, represent what we will call a symbiotic relationship wherein the concurrent performance on task B might even augment the

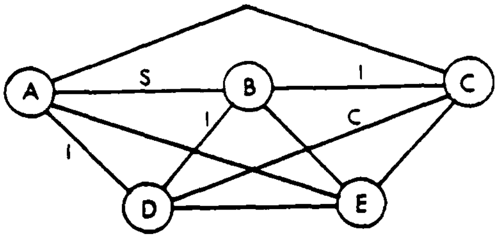

Figure 6. Network of five tasks with the links representing Symbiotic (S), Competitive (C) or Independent (I) pairwise relationships.

performance on A and vice versa. Tasks D and C represent a more probable type of relationship--a competitive relationship. If both demand 70% of the available resources separately, then their competitive relationship would imply that their joint performance might demand more than the simple sum of their separate demands--160%, Since the student can give only 100% in total, one or the other or both of the two tasks must suffer with the student in this overload situation.

The adaptive logic of the instructor model could do one of three things at this point. First, the student could be trained in isolation on task C until it reaches automaticity or becomes more resource efficient. Then when 10% of the resources in isolation produce the same required level of performance as a 70% investment did, task D could then be introduced. Because of the advance training on C, the joint demand of the two tasks is now manageable.

A second possibility for the adaptive logic of the instructor model would be to reduce the joint demand of the two tasks. This could be done by adjusting the adaptive variables on one or both of the tasks (e.g. the pace could be slowed by adjusting the airspeed of the approaching aircraft). This would be a more likely instructional strategy to take if the training of tasks in isolation presents a real compromise in simulation fidelity.

It may be that both previous approaches represent undesireable compromises, and that the overload situation simply cannot be avoided. The joint performance will simply have to suffer until practice eventually makes the tasks more resource efficient. In that case, the adaptive logic takes on the duties of resource budgeting. By telling the student to attend to, or concentrate on, one task more than the other, it would increase the rate in which that task would be mastered (become resource efficient). As discussed previously, the job of the instructor model would be to solve for the optimal allocation of resources during the joint training of C and D. Thus in order for the intelligence of the system to possess the flexibility to generate event-driven exercises such as the simulated aircraft approaches, the instructor model would need to incorporate a network representation of pairwise relationships regarding resource requirements between tasks.

MODEL OF THE STUDENT

In addition to the representation of knowledge, all the training systems described previously have some method for representing the student in his progress through the course. One form of the representation is to view the student as a growing subset of skills or knowledge units. The system keeps a record of which skills have been mastered and which are left to be acquired. In its simplest form then, each skill or knowledge structure can occupy one of only two states: learned or unlearned. Goldstein (1979) in his genetic graph, provided a different technique for representing the progress of a skill. Instead of representing the skill at a single location in the network wherein the skill occupied one of two learning states, he represented the skill at several locations in the graph wherein the various locations represented evolutionary stages. His reasoning was that it is not really the same skill at those various locations but rather qualitatively different and increasingly refined versions of the skill.

What we would require in our ideal system is possibly both forms of representation: first, a single location multi-learning state representation for structural units that do not undergo change as they are learned (see Atkinson, 1976); and secondly, a multi-location representation, such as in the genetic graph, when the skill or structural unit undergoes some transformation or refinement as learning progresses. We would also desire thirdly, a continuous representation of the strength of a skill or schema. This last requirement would yield information regarding the degree of automaticity of a skill which should be represented. Finally, we would also desire to the extent possible, that the representation of the progress of a structural unit be formalized in stochastic form, which would allow the adaptive logic in the system to optimize its instructional decisions (see Chatfield and Gidcumb, 1977).

SELF MODIFICATION PROPERTIES

An additional and desireable property of an intelligent system is that it have the capacity for self modification. As the instructor model obtains additional data from the students, it would be able to benefit from that experience and become a more efficient training system. Examples of such benefits are discussed by Atkinson and Paulson (1972), Atkinson (1976), and Chant and Atkinson (1973). The improvements in these examples cited, come mainly through increased precision in parameter estimation for the student models. One benefit comes from the increase in precision in the optimization algorithms, which are dependent upon the parameter estimates. A second benefit comes from qualitative changes in the student model based on the additional data. As an example, Atkinson and Paulson (1972) report using the Random Trials Increments (RTI) model (Norman, 1964) as the model of the student. As is characteristic of the RTI model, variation in the parameter can change its qualitative nature from that of an all-or-none process to an incremental process as extremes. By letting the parameters be estimated empirically, the most representative mix of these two models can be found. Further, the representation improves with added data from additional students. This principle of self-adjustment through empirically derived estimates controlling a process, could be generalized to portions of the system other than just the student model.

THE BRIDGE BETWEEN 6.1 and 6.2 CONTRACTING

What we have just described are the desireable characteristics of an instructor model which at the present time does not exist. First the instructor model should be able to deal with process as well as structure. This means that its scheduling, generative, and adaptive functions should reflect dynamic estimates of the students' resource allocation functions. Second, the instructor model would also need a knowledge representation system capable of representing process as well as structure. Third, there would be a need for adequately descriptive student models and finally a set of algorithms for self modification.

Currently there exists several prototypes of the characteristics we have just described in the 6.1 or basic research literature. Many of the efforts were funded by ONR. Most all of the 6.1 level of efforts tend to be oriented toward certain technologies such as the representation of knowledge, speech recognition, etc., which are directed toward no single particular training system, but could be incorporated into several. Subsequent levels of effort (6.2, 6.3, etc.) are usually more product oriented rather than technology oriented. That is to say that 6.2, etc. contracts are usually organized with a particular end-product in mind, e.g. an LSO part-trainer. Figure 7 illustrates this situation.

Note that there is a gap shown between the 6.1 and 6.2 levels. This is to illustrate the fact that most 6.2 or product-oriented contractors do not view the 6.1 level technologies as being in a "ready-to-implement state." This in fact would be the case in terms of the technologies required for the instructor model just described. Before the instructor model could be incorporated into an LSO trainer, considerable developmental effort would be required.

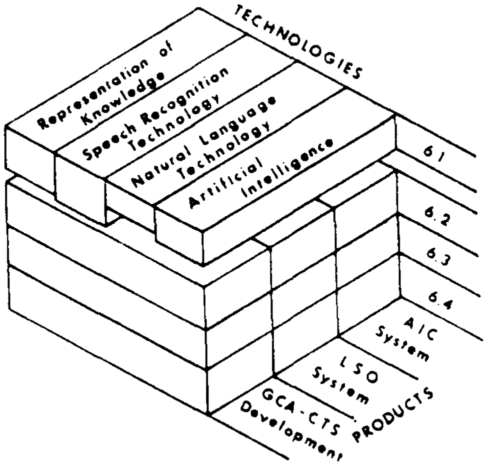

Figure 7. Present organizational structure of R&D effort

Part of the reason for the gap is that for the most part, two different groups of researchers are involved. The 6.1 level researchers are mainly university scientists with theory as their goal, while the 6.2 levels are industrial scientists with time-frame contingent products as their goal. Thus, one part of the problem is the breakdown in the crossfeed of information and technological needs caused by the lack of having both types of researcher engaged in both levels of contracting.

Figure 8 illustrates one possible solution to this dilemma, namely a series of 6.1 or 6.2 efforts aimed at bridging the gap. These efforts would have as their goals the synthesis and aggregation of the more theoretical technologies into applied technologies such as the development of the instructor model just described. These intermediate levels of effort would have to cross, or be applicable to, a number of product-oriented efforts in order to be cost-effective. In the case of the instructor model, a form general enough to be implemented in several trainers would need to be developed so that the cost of development could be amortized over several trainers. Finally, those involved in these efforts should be the 6.2 level researchers or at least personnel that would be in a position to follow and consult in the creation of the trainers throughout their various stages of development.

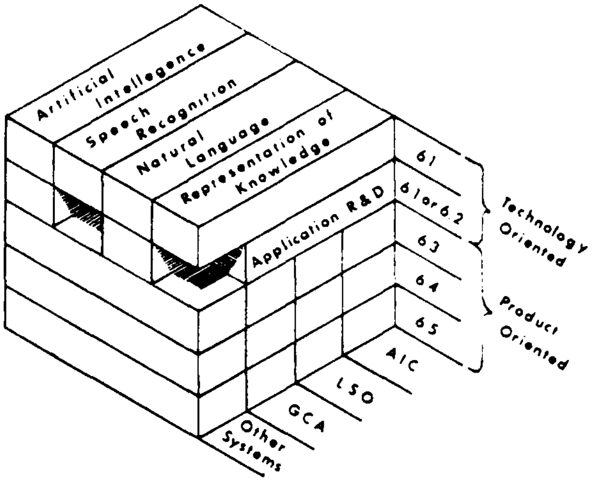

Figure 8. Proposed organizational structure of R&D efforts.

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ERRATA NOTICE NO. 1	Please make a pen correction on page 49 in Naval Training Equipment Center Technical Report IH-320 dated 22-23 January 1980.

PROCEEDINGS
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Human Factors Laboratory
Naval Training Equipment Center
Orlando, Florida 32813

22-23 JANUARY 1980

On page 49 the affiliation of Mr. John Boldon should be changed to the University of Central Florida.

After corrections are made, this notice is to be inserted at the front of the report for record purposes.

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