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DESIGN STUDY FOR AN AUTO-ADAPTIVE LANDING SIGNAL OFFICER (LSO) --ETC(U)

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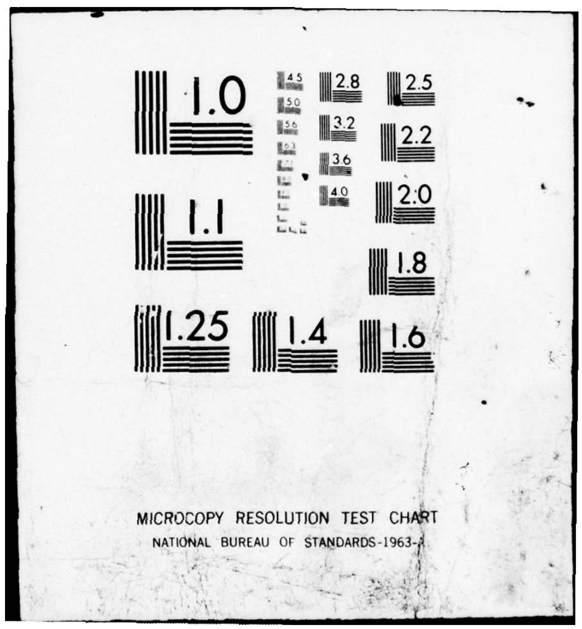
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Technical Report: NAVTRAEQUIPCEN 77-C-0109-1

DESIGN STUDY FOR AN AUTO-ADAPTIVE LANDING SIGNAL OFFICER (LSO) TRAINING SYSTEM

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This final report describes candidate performance capability requirements for an automated, adaptive Landing Signal Officer (LSO) training system. The system includes adaptive training control, a wide-angle visual system, automated speech understanding, automated performance measurement and a simulated LSO workstation. The report traces the derivation of system capabilities by addressing LSO job analysis, LSO training requirements, system utilization syllabus, system functions and assessment of relevant technology. The report also includes the

design of a laboratory system for concept demonstration and experimentation. A significant bibliography is included.

FOREWORD

At present, LSO qualification is a direct result of experience gained by observing and controlling aircraft under the supervision of a senior LSO. For a number of reasons, including a budget-induced decrease in the tempo of shipboard operations, the fleet is producing fewer qualified LSOs. The potential existence of less proficient LSOs could result in decreases in both safety and operational effectiveness. An increase in the carrier landing accident rate is totally unacceptable.

In the event that the trend toward reduced flight hours is reversed, the career LSO would still have a serious problem in maintaining proficiency when not deployed aboard ship. Since there is little prospect of significantly increasing the flying hours essential to the current method of LSO training, the solution to the problem clearly lies elsewhere.

This report presents the functional design for an aircraft independent, automated LSO training system. A capability is provided for standardized observation and control of various aircraft under various conditions. The system design provides both initial training of LSO decision-making behavior as well as continuing proficiency maintenance. The next step will be the implementation of the "paper" system into a laboratory system for evaluation of decision-making training and for specification of visual system requirements.

R. BREAUX, PhD
Scientific Officer

PREFACE

The authors are indebted to the Navy's LSO community for contributions which helped to orient this study to the real needs of LSO training. Appreciation is extended to the many marketing representatives, engineers and laboratory personnel in industry and in government who provided information, materials and demonstrations relevant to this study. In particular, the authors wish to acknowledge the efforts of the following: The type Commander LSOs, LCDRs John Birch (COMNAVAIRLANT), Bill Ostheimer (COMNAVAIRPAC) and Dave Maxwell (CNATRA) who were invaluable for their coordination of LSO participation and review of the study results. Ms. Janice Eisele, Dr. Robert Breaux and Mr. Don Norman of the Naval Training Equipment Center Human Factors Laboratory who provided meaningful study guidance and shared their expertise to enable effective focus on many of the critical issues of the study.

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SECTION I

INTRODUCTION

This report describes activities and results of analyses relating to the applicability of an automated, adaptive training system to the Navy's Landing Signal Officer (LSO) training program. The report serves as a basis for subsequent design efforts in the development of a cost-effective training system for the LSO. Significant training and technological issues relevant to LSO training are identified and described. The direction for system development and implementation is also provided.

The organization of the report is oriented to the timing of study activities which provides a logical flow of explanatory information and design rationale. Section II introduces the LSO training problem, the role of the LSO, and study methodology. Section III provides a description of the LSO job and LSO training needs. Section IV addresses the applicability of automation and adaptive concepts to LSO training. Section V addresses both the functional characteristics and the technological uncertainties associated with an LSO training system. Section VI describes a laboratory system design for concept demonstration and technological investigations. Section VII presents a summary of study conclusions. Section VIII presents recommendations for subsequent activities in system development and for enhancement of LSO training.

SECTION II

BACKGROUND

PROBLEM DEFINITION

There are multiple problems in LSO training which are reflected in the insufficient numbers of qualified LSOs, limitations in LSO skill levels, and reductions in LSO proficiency levels. The primary causal factor contributing to these problems is the reduced tempo of carrier operations which has evolved over the last several years. Figure 1 graphically depicts this reduction. LSO performance is reflected in two primary tasks, the training of pilots and the control of aircraft landings aboard ship. The LSO's task of controlling aircraft landings attracts the most attention due to its real-time visibility in carrier operations. Training for this position has been conducted over the years with an apprenticeship, on-the-job training (OJT), strategy. The effectiveness of this strategy is therefore very dependent on the availability of carrier operations for providing adequate learning conditions. Recent trends in the reduction of carrier operations following the Vietnam conflict are therefore adversely influencing LSO training.

The reduction of carrier operations has a three-fold effect on LSO training and job performance. The first effect, and probably the most obvious, is the decrease in availability of the primary medium for the LSO training program. This is caused by fewer landings for the LSO trainee to observe and control thus impacting LSO skill acquisition and the availability of skilled LSO's. The trainee often does not have enough time in his tour of duty to complete the training program. The second effect is due to the increase in time between carrier operating periods. This causes longer periods of LSO inactivity which reduces job proficiency in the skilled LSO. The third effect, reductions in pilot proficiency due to curtailed carrier operations, places increased demands on LSO job skills.

Other problems are evident in LSO training. Non-LSO duties and schooling requirements interfere with the efficiency of LSO participation in training. LSO performance evaluation is very subjective. There is inadequate structure and standardization pertaining to LSO training.

The problems, evident in LSO training, point toward several candidate solutions. A very valuable and measurable goal is the reduction of calendar time required for LSO training to develop a productive LSO. Candidate improvements to LSO training include reinstating adequate levels of carrier operations, restructuring the overall LSO training program, implementation of quality academic media, and development of a cost-effective training system. Optimization of LSO training would probably be best accomplished through a combination of the candidates. Since there is a high probability of carrier operations remaining at a reduced level, the most effective

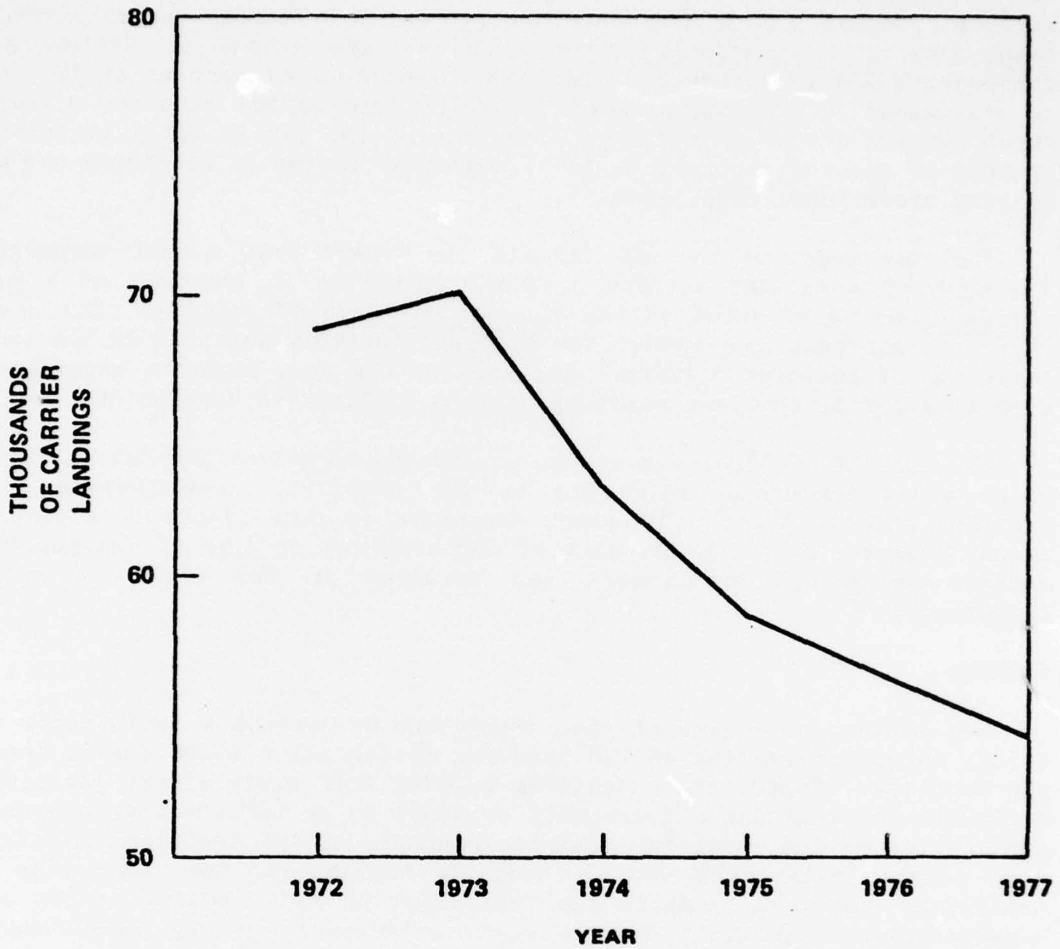

Figure 1. Reductions in Carrier Landings

single improvement to be pursued is the development of a cost-effective training system. This system is envisioned to provide a replication of a significant portion of the operating environment. The system has excellent potential for improving the efficiency of LSO training and for supporting both LSO skill acquisition and skill maintenance. Pursuit of this system appears feasible at this time in view of recent advances in training technology, especially in the fields of visual simulation, speech understanding, and adaptive training.

ROLE OF THE LSO

The LSO plays a critical role in the safety and readiness of the Navy's carrier strike forces. Carrier landings under adverse environmental conditions and with aircraft or carrier recovery system malfunctions are difficult and have the potential for disastrous results. The LSO is responsible for preparing pilots for these contingencies and assisting them in the recovery process. Many accidents are prevented by timely and effective LSO interventions. Conversely, many accidents are caused or influenced by ineffective LSO performance. The combat readiness of carrier strike forces is influenced by the efficiency of carrier landing and recovery activities which support strike operations. The role of the LSO in pilot training and control of recovery operations is an important factor in attaining and maintaining operational efficiency.

The importance of the LSO can also be viewed from a cost perspective. The cost of a carrier landing accident resulting in the loss of a single aircraft can be measured in the tens of millions of dollars. The cost of losing an aircraft crew member can be quantitatively measured in the tens of thousands of training dollars. The loss of the crew member's experience is even more costly to fleet readiness from a qualitative standpoint.

The quality of LSO training has an obvious impact on LSO job performance which gives increased importance to the continual re-evaluation of LSO training effectiveness. The study described in this report is a result of recent concerns with the adequacy of LSO training in view of changes in the carrier operations environment and advances in the field of training technology.

CHARTER

The primary objective of this study was to develop a performance capability specification for an LSO training system which would enable improved LSO training. Supportive objectives guiding this study effort included the definition of training requirements relevant to an LSO training system, the application of auto-adaptive training concepts to LSO training, the assessment of the state-of-the-art in training technology, and the design of a laboratory system to support the resolution of LSO training system design uncertainties. Implicit in the study objectives was the requirement to provide recommendations for the subsequent activities needed to demonstrate training system concept feasibility and to resolve system design uncertainties.

TECHNICAL APPROACH

The technical approach for this study was a systematic, analytical process oriented toward providing system design traceability and LSO training application accountability. Since this effort was essentially a requirements study, relevant to the support of an identified operational need, the approach included provisions for extensive user (LSO) involvement.

Several professional disciplines were identified for application to this effort. These included training analysis, experimental psychology, systems analysis, software design, and hardware engineering. Experience with training systems applications was an important criteria in the selection of individuals from within these disciplines. The experience factor enhanced technical communications among the study participants. Familiarity with aircraft and carrier operations on the part of several project participants helped to enable effective interface with the LSO community.

The technical approach for this study involved six major tasks. The tasks and their primary interrelationships are depicted in Figure 2. Generally, the early portion of the study was devoted to analytical tasks concerned with the identification and generation of baseline system design data. The latter portion of the study involved the synthesis of this data to establish system design and implementation concepts. However, there was frequent interplay and overlap among tasks which made it very difficult to depict a step-by-step flow of task accomplishment.

Definition of LSO training requirements consisted of analyses of the existing training program, training problems, operational tasks and the LSO's operating environment. This enabled the definition of LSO training requirements in the form of behavioral objectives. The delineation of candidate LSO training system functions consisted of the systematic identification of functional elements which would provide a training environment for task performance, performance evaluation, and instructional control. The

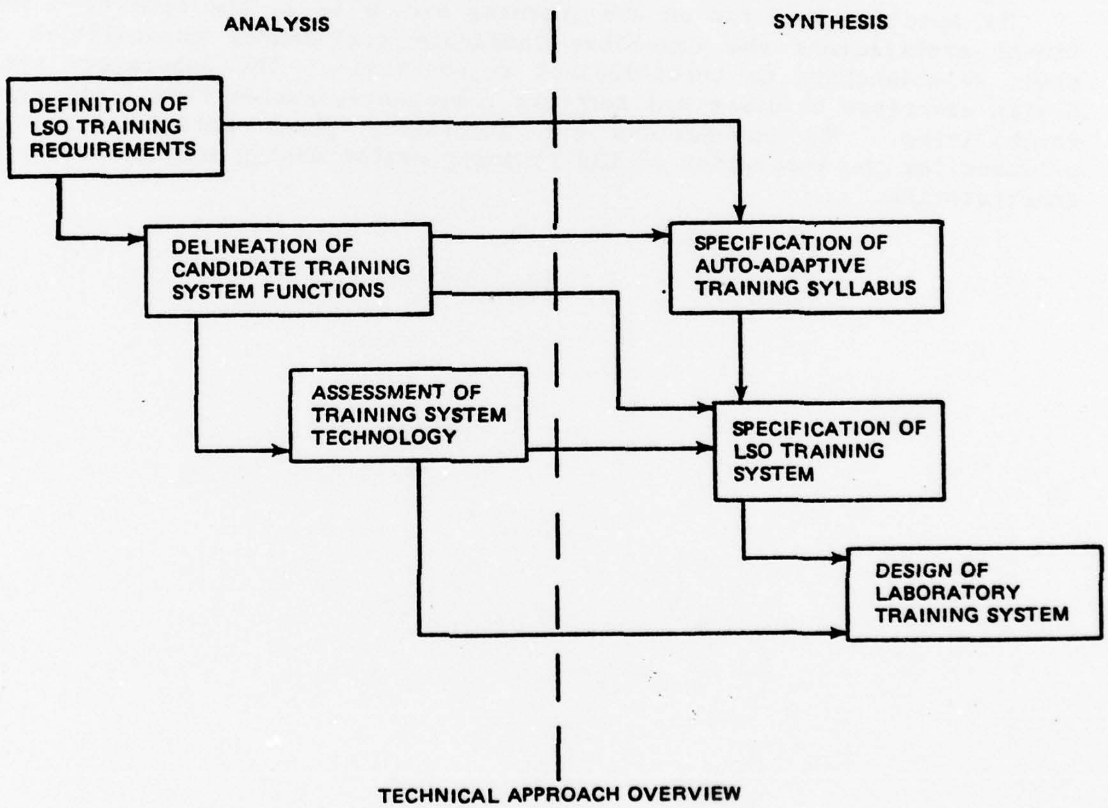

Figure 2. Technical Approach Overview

assessment of training system technology involved the collection and analysis of technical data for systems and techniques relevant to candidate LSO training system functions. This was accomplished through literature search, technical discussions, and system observations. Specification of an auto-adaptive training syllabus was made by the determination of the applicability of auto-adaptive training concepts to LSO training and the development of a preliminary syllabus supporting LSO training requirements. Specification of an LSO training system involved the delineation of functional performance capabilities and the identification of technological capabilities for performing system functions. Design of a laboratory training system was accomplished by the determination of laboratory phase needs and the assessment of NAVTRAEQUIPCEN laboratory equipment capabilities.

STUDY RESULTS

The primary results of this study include the functional performance specification for an LSO training system, the design for an interactive laboratory system and recommendations for subsequent laboratory phase activities.

The specification for an LSO training system is in the form of a functional architecture and describes candidate performance capabilities and their relationships to technological capabilities. The laboratory system design describes hardware and software components, system flows, and system capabilities. Recommendations for laboratory phase activities provide guidance for the resolution of LSO training system design and implementation uncertainties.

SECTION III

LSO TRAINING REQUIREMENTS

INTRODUCTION

This section presents the training requirements of the LSO in terms of behavioral objectives and describes the results of analyses supporting their definition. Included in this section is a comprehensive description of LSO training and its problems as well as an analysis of the LSO job including the identification of LSO operational tasks and task cues.

APPROACH

There were three major activities involved in the definition of LSO training requirements: (1) analysis of existing LSO training, (2) analysis of the LSO job and (3) the definition of behavioral objectives. Instructional system development concepts influenced this effort. Significant LSO involvement was utilized for data collection and review. A thorough analysis of the existing LSO training program was conducted in order to ensure the identification of critical deficiencies and candidate problem solutions. Significant emphasis was placed upon the identification of LSO tasks, task cues, and performance influences in order to form a job-related foundation for the training requirements. The training requirements for the LSO were defined in observable and potentially measurable terms in the form of behavioral objectives.

Data for analyses of LSO training and the LSO job resulted from documentation review, group and individual discussions, and questionnaire responses. Documents reviewed included Navy directives, prior studies of the LSO, the Phase I school syllabus, articles from Navy professional journals, and a Naval Safety Center summary of carrier landing accidents.

Group and individual discussions were conducted with LSOs from most major Naval Air Stations and from the Naval Air Training Command. Five formal group discussions were conducted in the course of this study. Two were held on the east coast and three on the west coast. (See Appendix B.) Each was preceded by a formal briefing of the objectives and methodology of the study in order to promote meaningful discussions of LSO training and the LSO job. Individual discussions were primarily oriented toward the clarification of specific information from other sources. The most frequent individual discussions were held with the type commander LSOs (COMNAVAIRLANT, COMNAVAIRPAC, CNATRA) through personal visits or via telephone. The group and individual interviews involved qualified LSOs from all aircraft communities.

Questionnaire responses were a fruitful source of training requirements data. A questionnaire was developed based on initial documentation review and consultation with senior LSOs. The questionnaire solicited data concerning LSO selection, LSO training, task performance, task cues and waving strategies. A copy of the questionnaire and a summary of the questionnaire results appear in Appendix G. Approximately 180 questionnaires were distributed among LSOs within all aircraft communities on both coasts, in the training command and on overseas deployment. Fifty-four questionnaires were returned and among them all aircraft communities were represented.

A supplementary source of job analysis data was Human Performance Research, Inc. (HPRI). They were conducting a concurrent study of LSO behavior to develop a computer-based model of LSO performance. Frequent discussions were held with HPRI's project director to compare data and analytical results. Preliminary results of the HPRI analysis and the job analysis efforts of this study were verified by the type commander LSOs.

The derivation of LSO behavioral objectives was accomplished through an evaluation of the job analysis results. This involved consultation among training analysis and behavioral psychology personnel to identify LSO waving behaviors which are observable, potentially measurable, and indicative of learning achievement.

EXISTING LSO TRAINING

LSO training is primarily characterized by an apprenticeship strategy of knowledge and skill acquisition. During the Vietnam conflict, this on-the-job-training (OJT) strategy proved very effective due to the high level of carrier operations and the short turnaround periods between deployments. The tempo of carrier operations has lessened and the Navy is facing problems with both the quantity and quality of skilled LSOs. Reducing time requirements for LSO training is an important goal of LSO training problem solutions. In the following paragraphs LSO training is explored and training problems are analyzed.

DESCRIPTION. Selection of an individual to become an LSO trainee consists of several criteria. The first criterion is that he be a pilot. The LSO selection process is based upon "...motivation, aviation ability, and potential as an instructor".[1] The current policy is to identify candidate LSOs during advanced pilot training based on pilot performance and on LSO potential. Since this is a recent policy change, most candidate LSOs still are selected during their first fleet squadron tour of duty.

The LSO training program has two separate stages of learning activities, structured and unstructured. The early stage guides the candidate LSO through two clearly defined phases. Phase I is Basic Training and consists of attendance at the LSO Phase I school at Pensacola, Florida. This formal

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[1] Office of the Chief of Naval Operations. The Naval Air Training and Operating Procedures Standardization Program (NATOPS) manual, Landing Signal Officer (LSO NATOPS). Department of the Navy, 1975.

school was established in 1974 and covers a nine working day period. Prior to 1974, Phase I training was conducted by the type commander LSO over a 2-3 day period. The school curriculum consists of classroom sessions and field trips for equipment familiarization and for observation of Field Carrier Landing Practice (FCLP) and carrier operations. The objective of the curriculum is to provide an LSO trainee with "...an understanding of the theory of LSO operations as well as a knowledge of field and shipboard equipment and systems which fall within the LSO specialty"[2] and is oriented toward a totally inexperienced candidate LSO. The field trip aboard a carrier occurs only if a carrier (usually the USS Lexington) is available and is primarily for the benefit of the totally inexperienced trainee. The school staff consists of three qualified LSOs and a senior aviation boatswain's mate. Questionnaire results presented in Appendix G indicate that knowledge gained about pilot landing aids and carrier recovery equipment is the most beneficial aspect of the school.

Phase II involves training in the control of FCLP operations. This training is broken into two parts, observation and control. LSO NATOPS specifies that the trainee will observe and control air wing aircraft under normal day and night conditions and utilizing the Manually Operated Visual Landing System (MOVLAS). LSO NATOPS also calls for the trainee to present ground training lectures concerning FCLP operations. In actual practice, Phase II training occasionally includes the control of only a single type of aircraft and frequently does not include the use of MOVLAS. Upon completion of Phase II training, the trainee is formally designated as field-qualified which means that he can control FCLP operations without supervision.

Phase III is unstructured and involves the observation and control of air wing aircraft aboard ship. There is no specified end to this training phase which implies that Phase III covers all subsequent LSO training and qualification level progression. The descriptions of the qualification levels provide the only guidance for the accomplishment of Phase III training. The first qualification level is the designation category of Squadron LSO which "reflects the individual's ability to satisfactorily control one or more type aircraft aboard ship in daylight conditions".[3] Attainment of this level usually occurs during the LSO's first overseas deployment aboard ship. The second designation category is Wing LSO, which "reflects an individual's ability to control a majority of the air wing aircraft aboard ship in day/night, all weather and deck conditions without assistance...".[4] Attainment of this level usually occurs during the latter portion of the LSO's second overseas deployment, after the LSO has spent some time in a

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2 Chief of Naval Air Training, CNATRA Instruction 1542.39A: Curriculum, Phase I Landing Signal Officer. NAS Corpus Christi, Texas, September 2, 1976.

3 See footnote 1, page 16.

4 See footnote 1, page 16.

supervisory capacity. The third designation category is Training LSO, which "reflects the individual's demonstrated ability to administer, instruct and supervise initial in-type carrier qualification".[5] This category is usually attained during a tour of duty as an instructor in a Readiness Squadron (initial pilot training in a fleet type of aircraft) or a Training Squadron (initial pilot training). The highest category is Staff LSO which "reflects the attainment of the highest level of qualification and experience gained as a result of performance in subordinate categories".[6] It is desirable that an individual achieve Wing LSO designation in his first tour of sea duty (approximately a three year period in which about 15-20 months are spent operating aboard ship) and then spend a tour of duty (usually two years) as a Training LSO prior to attaining Staff LSO designation.

The time required to attain the various LSO designation categories described above is variable. LSO training progress is dependent on many factors including individual learning rates, amount of exposure to carrier operations, shortages of LSO instructors, expediency (needs of the fleet), LSO motivation, interference from other duties, etc.

Evaluation of LSO performance in training and on the job is very subjective. The responsibility for evaluation rests with the senior LSO present, usually an Air Wing LSO in the fleet, or a Training Wing LSO in the training command. The senior LSO also draws on the judgments of other LSOs at the Wing LSO designation level who have supervised the individual. The only performance evaluation guidelines are the criteria for the various designation levels which were described earlier. Questionnaire results presented in Appendix G indicate that <u>reaction under stress</u> is the primary measure of LSO performance quality. Other key criteria include perceptual ability, motivation, and the ability to instill confidence in pilots.

Refresher training for skilled LSOs returning from non-LSO tours of duty is informally conducted by the senior LSO present, usually the Air Wing LSO. There are no documented guidelines for this training but it involves a brief period of observation followed by a brief period of supervised control of aircraft. The type commander LSOs closely monitor and sometimes directly supervise refresher training for LSOs going to Air Wing LSO jobs.

PROBLEMS. Problems in LSO training are reflected in the existence of LSO shortages, and reduced LSO skill and proficiency levels. The primary causal factor appears to be the reduced tempo of carrier landing operations, which includes reductions in the number of carrier landings and increases in the turnaround time between carrier operating periods. As mentioned earlier, carrier landing operations are the primary medium for the acquisition of LSO skills. Experience in observing and controlling carrier landings provides the LSO with an environment for acquiring basic skills, practicing those

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[5] See footnote 1, page 16.

[6] See footnote 1, page 16.

skills, and using those skills under a variety of complex situations. The highly cognitive nature of controlling aircraft landings aboard ship necessitates extensive exposure to many situations in order to prepare the LSO for effective decision making in unexpected circumstances. A shortage of carrier landing operations impacts the availability of skilled LSOs. The fast learning LSO trainee can generally reach a productive skill level (Wing LSO) during his first tour of sea duty. However, the slower learner is frequently unable to complete the OJT program. This is due to the inability of the LSO training supervisor to devote adequate instructional attention to him during landing operations and to the shortage of supervisory LSOs. The decreased pilot proficiency caused by reduced carrier operations frequently influences operational commanders to demand that the more experienced LSOs do most of the controlling of aircraft, especially under night conditions. This reduces trainee opportunities for "hands on" aircraft control. The questionnaire responses and LSO discussions indicate that frustration caused by slow training progress is a factor in the attrition of LSO trainees. The questionnaire results also support the point that more control of landings is needed in Phase III training prior to achieving Wing LSO designation.

Reductions in carrier operations adversely affect the proficiency of the skilled LSO and provide less opportunities for skill enrichment. This is reflected more in the admitted apprehension of LSOs returning to the carrier after long lay-offs than in any objective terms. As expected, this effect is most apparent among qualified LSOs with minimum experience levels. Reduced carrier operations decrease the exposure to unusual operating conditions and complex landing situations. This, in turn lessens the enrichment of LSO skills. For example, there are several experienced LSOs at the Wing LSO and Staff LSO designation level who have never observed the recovery of an aircraft into the barricade aboard ship. This is an emergency situation which places extreme demands on LSO skills. It involves the control of an aircraft, usually experiencing a significant malfunction, in operating conditions which require very restrictive control of aircraft approach parameters.

Reductions in carrier landing operations have another effect on the LSO. Pilot skill and proficiency levels are decreased thus increasing the demands upon LSO skills. During a carrier landing the pilot and LSO performances are complementary. A skilled pilot requires less assistance from the LSO than does an unskilled pilot who is less predictable in his landing performance. Both of these factors increase the demands on LSO perceptual and decision-making skills especially when controlling a landing in adverse operating conditions or emergency situations.

There are other factors which impact the quality of LSO training. One of the most significant is the absence of objective LSO performance evaluation. Evaluation is totally dependent upon the judgments of supervisory LSOs. This occasionally leads to different standards of performance among LSOs causing discouragement on the part of the trainee. Subjective evaluation enables personality differences to influence trainee learning progress and attitudes. The type commander LSOs can only track the progress of both skilled LSOs and trainees by frequent discussion with supervisory LSOs and actual performance observation. There is no objective method for measuring LSO proficiency levels nor is there an objective measure of achievement in refresher LSO training. The dependence on supervisory LSO judgment in LSO performance evaluation based on vague evaluation guidelines places a heavy burden on the supervisory LSO. The supervisory LSO may unnecessarily delay qualification of a trainee or he may prematurely qualify a trainee. Both errors have a potentially negative impact on the quality of LSO training and job performance. The first case delays the availability of a productive LSO and may lead to trainee discouragement and attrition. The second case could have disastrous results in an emergency landing situation.

Some additional deficiencies noted in the course of this study deal with training program structure and resources. Selection of candidate LSOs is based on subjective criteria. There has been general improvement in the selection process in recent years but there is room for increased objectivity in the criteria. There are occasions when candidates are selected involuntarily. This violates adherence to the criteria stated in LSO NATOPS (i.e., "motivation"). Phase I training has been significantly improved with the establishment of a formal LSO school. Although still in a transitionary stage of existence, the performance of recent school graduates is very promising. There is, however, room for improvement in the quality of training media provided to the school staff and in the evaluation of student achievement of curriculum objectives. Phase II training guidelines are vague. The questionnaire results in Appendix G indicate that there is insufficient practice for the trainee in controlling aircraft and in using the MOVLAS. Frequently, the trainee becomes field qualified with experience at controlling only one type of aircraft. Phase III training lacks sufficient emphasis on use of the MOVLAS. This problem varies in intensity within the fleet. The worst cases cited were usually caused by command non-support, a factor frequently beyond the control of supervisory LSOs. Significant work demands and uncertain operating schedules frequently interfere with the effectiveness of LSO training. The trainee usually has other squadron duties including his pilot duties. Special flight operations evolutions and assignment to various Navy schools often curtail the trainee's opportunities for OJT or degrade the continuity of his training. The absence of a well-structured and centrally-managed LSO training program enables these training inefficiencies to exist. Table 1 summarizes LSO training problems and candidate solutions.

CANDIDATE SOLUTIONS. There are several candidate solutions for the various problems in LSO training. <u>The goal of problem solution is to reduce the calendar time required for training an LSO to a productive level (Wing LSO).</u> Based on information presented earlier, an obvious solution would be to increase Navy carrier landing operations. This would reinstate the training program's primary medium to an improved level of availability. Another solution would be a study of total LSO training needs leading to improved guidance for the conduct of the LSO training program. This would support better definition of trainee learning goals and more efficient utilization of training resources. Implementation of quality media would provide significant improvements to the LSO training program. This would include consideration of additional academic media for the Phase I school, academic

TABLE 1. LSO TRAINING PROBLEMS AND SOLUTIONS

<u>TRAINING PROBLEMS/CAUSAL FACTORS</u>

Reduction in carrier operations
Inadequate training program structure
Inadequate training implementation guidelines
Subjective LSO performance evaluation
Training discontinuity
Subjective LSO trainee selection criteria
Shortage of skilled LSOs
Non-LSO task interference
Excessive length of existing training program
Extensive periods of LSO skill inactivity
Reduced pilot proficiency

<u>CANDIDATE PROBLEM SOLUTIONS</u>

LSO training system (task training media)
Improved training program structure
Improved training implementation guidelines
Quality academic media
More objective LSO performance evaluation
Increase carrier operations
More objective trainee selection criteria
Increased command attention to LSO training

media packages to supplement OJT, part-task trainers, and sophisticated interactive training systems which replicate the job environment. Development of more specific, standardized guidelines for subjective LSO performance evaluation would be a candidate solution; the development of an objective performance evaluation system would be an even better solution. Investigations into improved LSO candidate selection criteria could lead to a decrease in the trainee attrition rate and an improvement in training program efficiency. Increased command attention to the importance of LSO training and the need for command support of the training program would alleviate some training inefficiencies.

Optimization of LSO training requires the implementation of all the above solutions. A less ambitious, and less costly, solution is needed as it is probable that carrier operations will remain at a reduced level, and may decrease even more. The causes of the most significant problems in LSO training appear to be ineffective training guidelines and an inadequate learning environment for efficient job skill acquisition and skill maintenance. These two causal factors point toward <u>two separate but related solutions</u>: (1) <u>the development of an improved training program structure</u>

and implementation guidelines; (2) the development of an LSO training system supportive of both skill acquisition and skill maintenance. The development of an LSO training system is the more important because of its potential impact on the most critical and visible aspect of the LSO, his control of aircraft landings aboard ship. Improved training program structure and implementation guidelines can be only moderately effective without a quality medium to counter the reduction in carrier operations.

The remainder of this report presents study results which provide guidance for the design and implementation of an LSO training system.

THE LSO JOB

The LSO has a significant responsibility within the carrier landing operations environment. During carrier landing activities his "primary responsibility is the safe and expeditious recovery of aircraft aboard ship. ...The LSO is also directly responsible for training pilots in carrier landing techniques".[7] In addition to controlling aircraft landings and training pilots, he is responsible for training prospective LSOs. All three of these responsibilities have a direct impact on the effectiveness of the Navy's carrier strike forces to prepare for and perform their missions effectively.

To fully appreciate the role of the LSO during carrier landing activities, one must understand what is involved in a carrier landing. The pilot attempts to fly the aircraft along a prescribed descent angle (glideslope) to the carrier deck. The desired outcome of his approach is to have the aircraft tailhook engage one of four arresting cables located on the deck near the centerline of the carrier's angled deck. Figure 3 depicts side and plan views of an approach.

There are three dimensions of primary concern to the pilot (and the LSO): (1) vertical positioning relative to the optimum glideslope, (2) lateral positioning (lineup) relative to the imaginary extended centerline of the angled deck, and (3) aircraft approach speed. The pilot's cue for the vertical dimension is the Fresnel Lens Optical Landing System (FLOLS), commonly referred to as the "meatball." The "meatball" is an amber light whose vertical positioning, relative to a set of green reference ("datum") lights, dynamically indicates the position of aircraft relative to the optimum glideslope. A simplified depiction of the FLOLS is presented in Figure 4. This system also includes two other sets of lights, "wave off" and "cut" lights, which are only visible when activated by the LSO. These will be discussed later in descriptions of LSO tasks. The pilot's cue for lateral positioning is the centerline of the angled deck. During the day he sees a yellow and white stripe. At night he sees a line of white lights which are

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[7] See footnote 1, page 16.

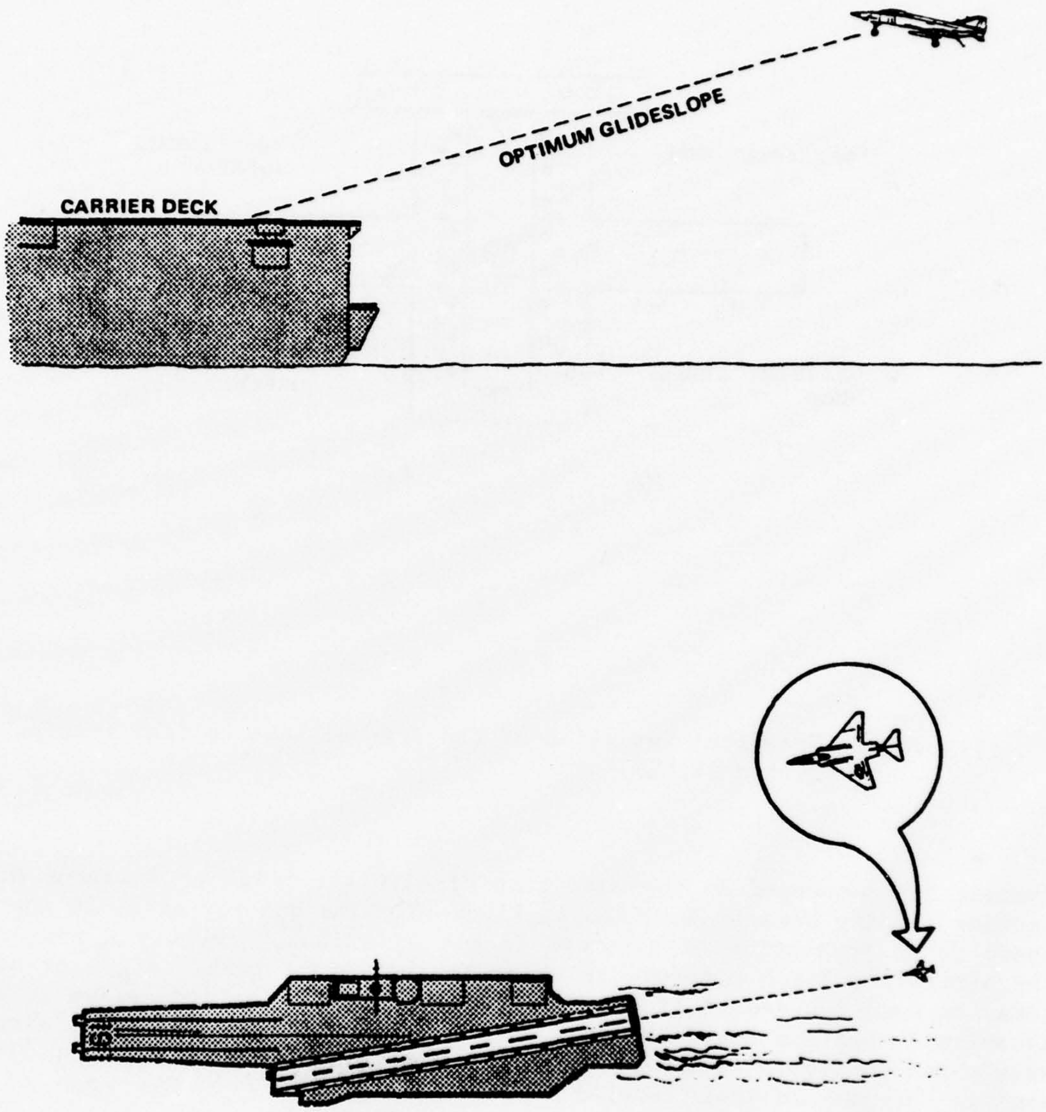

Figure 3. Side and Plan Views of Carrier Approach

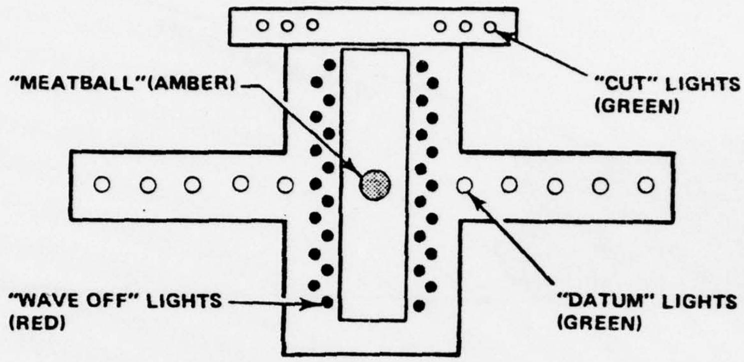

Figure 4. Graphical Depiction of the Fresnel Lens Optical Landing System (FLOLS)

dynamically sequenced in the direction of aircraft flight. A layout of the carrier landing area is depicted in Figure 5. The cue for aircraft approach speed is an indication of aircraft "angle of attack," roughly a measure of the aircraft's pitch attitude relative to the flight path. Angle of attack (AOA) is used instead of airspeed because it provides an indication of aerodynamically optimum approach speed which accounts for variations in aircraft weight and configuration. The primary indication of AOA is a set of lighted symbols in the cockpit located within the pilot's viewing area of the carrier deck.

Control of the three dimensions is very critical to landing efficiency and safety. Excessive deviations in the vertical dimension can result in a hard landing, missing the arresting cables, or worse, a "ramp strike" (aircraft crashing short of the landing area). Excessive deviations in the lateral dimension upon landing can cause structural damage to the aircraft and the ship's arresting gear, or could result in the aircraft hanging by the arresting cables over the side of the landing area. Excessive deviations in the speed dimension can result in aircraft stall during approach or can cause structural damage to the aircraft and the ship's arresting gear.

Subsequent paragraphs will describe in more detail LSO duties, responsibilities, job assignments, tasks, and task cues.

DUTIES AND RESPONSIBILITIES. The primary LSO responsibilities identified earlier (aircraft control, pilot training, and LSO training) have varying significance in the different jobs (billets) actually held by an LSO. Subsequent paragraphs describe these variations as well as the relationship of job responsibilities to LSO designation categories. Potential future changes to the LSO job are also reviewed.

The most fundamental billet held by an LSO is that of Squadron LSO (not to be confused with the designation category of the same name). This individual is primarily responsible for the training of pilots (requiring only proficiency training) in his own squadron. His duties include carrier operations briefings, pilot debriefings, control of FCLP operations, control of carrier landings by pilots in his squadron, maintenance of pilot landing performance records, continuing his own participation as a learning LSO, and advising the squadron commanding officer of pilot performance trends and problems. For these duties he answers to his commanding officer. However, depending on his designation category, he may have additional duties. The duties described above are most effectively performed by an individual with the designation of Wing LSO. Due to LSO shortages the billet may be held by an individual with only a field-qualified or Squadron LSO designation. If the individual has attained Wing LSO designation (or is approaching it) he usually acts as an LSO watch team supervisor and his duties include controlling all air wing aircraft and conducting LSO training. In this position he works for the Air Wing LSO.

There are two LSO billets which are similar in duties and responsibilities, Readiness Squadron LSO and Training Squadron LSO. The LSOs in these jobs are responsible for the initial carrier qualification (CQ) training of pilots for carrier landings. The Readiness Squadron LSO deals with qualified pilots who are transitioning to a different aircraft than previously flown. This training involves both day and night carrier landings. The Training Squadron LSO deals with pilots in undergraduate pilot training who have little or no experience at landing aboard ship. This training only involves day landings. An individual in one of these LSO jobs is designated Training LSO. The designation of Wing LSO is required prior to assignment to the job of Readiness Squadron LSO. A Training Squadron LSO may have accomplished all his LSO training while assigned to another billet in the training squadron.

The Air Wing LSO belongs to the Air Wing Staff which coordinates the operations of the squadrons within the wing. Prior to deployment aboard ship the Air Wing LSO is responsible for monitoring and evaluating the readiness of all air wing pilots to land aboard ship. He works closely with the Squadron LSOs to accomplish this. Aboard ship he is the senior LSO and

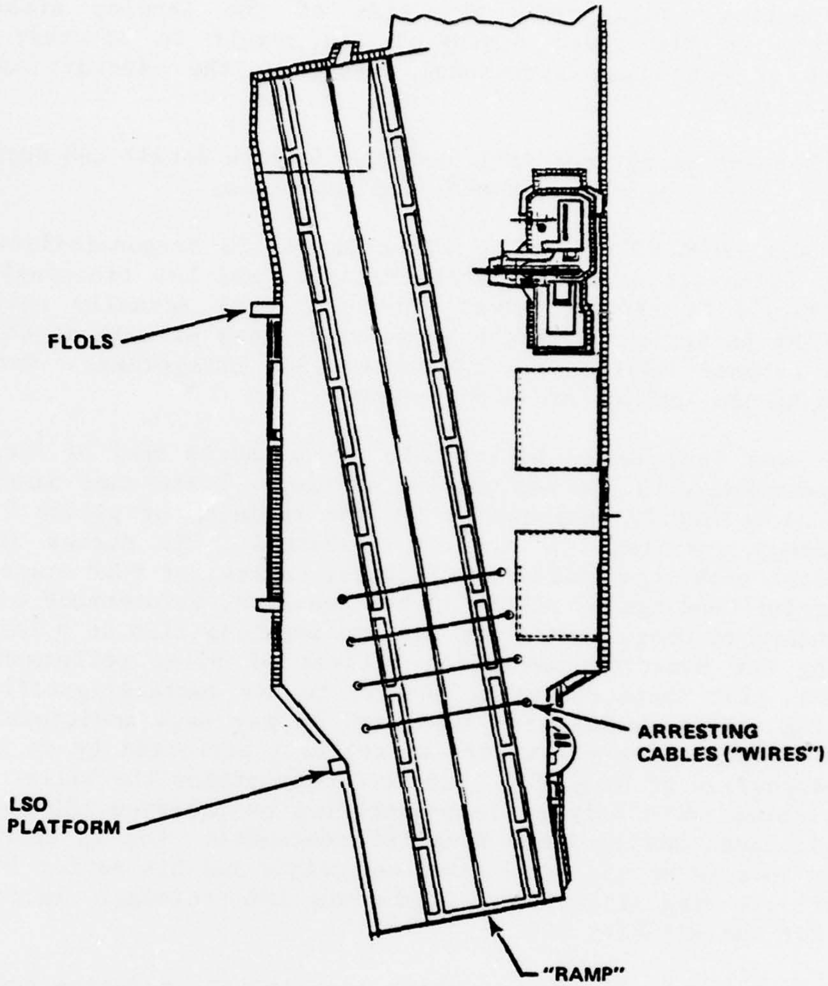

Figure 5. Typical Carrier Landing Area

is responsive to both the Air Wing Commander and to the ship Commanding Officer in carrying out his supervisorial LSO duties. He controls aircraft landings, supervises LSO teams, supervises LSO training (Phases II and III), and advises his superiors concerning pilot performance and operating conditions. To hold his billet the designation category Staff LSO is required.

The LSO works in a very dynamic and challenging operating environment, no matter which billet he holds. During carrier landing activities he must make critical real-time decisions in order to make timely advisories to his superiors concerning feasibility, safety and efficiency of landing operations. There are frequent pressures on him to place landing expediency above safety. Seldom does he perform his duties during landing operations without some portion of his equipment inoperable. Because of his flying and other duties he usually works longer hours than other pilots. His job performance errors are very visible and potentially disastrous. Successful job performance is less visible. Pilots seldom praise him but frequently criticize him for his evaluations of their landings.

There appear to be few significant changes in the role of LSO in years ahead. Some of his specific tasks may be modified by changes to LSO job aids, aircraft systems, and carrier recovery systems. Improvements in LSO displays and shipboard communications may simplify some of his perceptual and coordination tasks. Aircraft system changes may ease or complicate the pilot's tasks, thus affecting demands on LSO skills. Improved carrier recovery systems to ease both the pilot and LSO workload are a future possibility.

Investigation of the LSO job based on information outlined in the preceding paragraphs led to the identification of five job functions. The functions are depicted in Figure 6.

The control of aircraft landings aboard ship can be further divided into four elements:

a. Assess aircraft approach

b. Assess recovery conditions

c. Direct pilot actions

d. Advise superiors of recovery feasibility, efficiency and safety.

The conduct of FCLP operations and the control of aircraft field arrestments can both be divided into four similar elements:

a. Assess aircraft approach

b. Assess recovery conditions

c. Direct pilot actions

d. Coordinate pattern control.

Instructing pilots can be divided into four elements:

a. Conduct ground instruction (briefings, debriefings)

b. Conduct real-time FCLP instruction (pilot in aircraft)

c. Conduct real-time carrier landing instruction (pilot in aircraft)

d. Evaluate pilot training needs (based on records of performance).

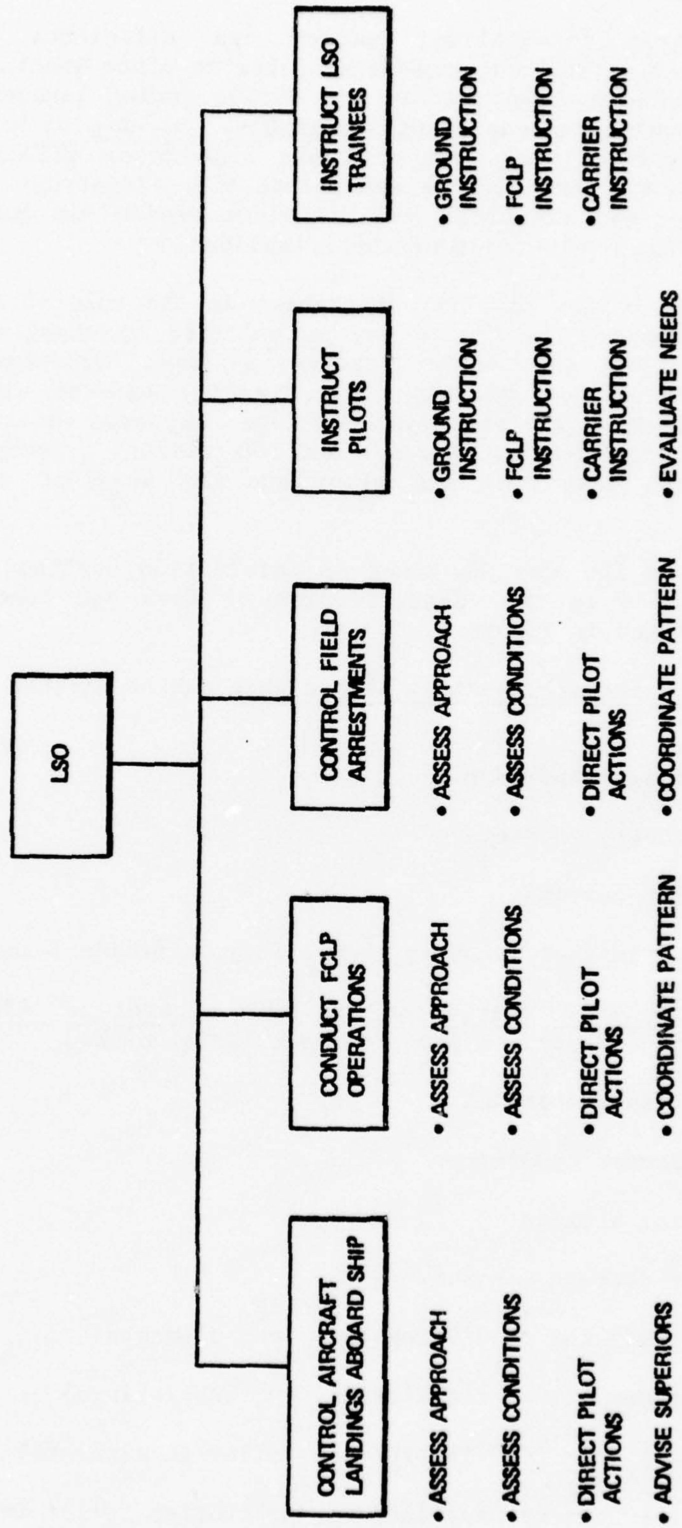

Figure 6. LSO Functions

Instructing LSO trainees can be divided into three elements:

a. Conduct ground instruction (briefings, debriefings)

b. Conduct real-time FCLP instruction (Phase II training)

c. Conduct real-time carrier landing instruction (Phase III training).

Based on preliminary evaluation of LSO training needs, the function of controlling aircraft landings aboard ship has been selected for further analysis in order to define the training requirements relevant to an LSO training system. The results of that analysis are presented in the next section.

OPERATIONAL TASKS/CUES. The LSO function of controlling aircraft is characterized by the real-time application of perceptual, decision-making and response skills in a complex operating environment. This involves "correlating factors of wind, weather, aircraft capabilities, ship configuration, pilot experience, etc., in order to provide optimum control and assistance in aircraft landings".[8] The means for assessing aircraft parameters and other situation factors are the LSO's visual and auditory senses. The means for providing control are radio voice communications and light signals.

A highly skilled LSO displays an apparent ability to anticipate or predict impending aircraft approach deviations and to provide relevant direction or advisories to the pilot. This is not "black art," however. It apparently is a reflection of an LSO's experience level, his ability to draw on that experience to subconsciously derive event occurrence probabilities. The broader the experience, the higher the probability of having been exposed to a similar set of approach conditions.

The LSO's assessment of an approach situation is a complex process due to the significant number of variables which must be considered. Influencing the assessment of these variables is the LSO's responsibility for both "safe" and "expeditious" recovery of aircraft. His decisions are frequently trade-off analyses since "safe" and "expeditious" are not always compatible. By only accepting minor approach deviations, thus increasing the frequency of the "waveoff" command, the safety factor is increased. However, this can have significant negative impact on recovery efficiency (rate of successful landings). Conversely, accepting large approach deviations may increase the efficiency of recovery but this could jeopardize landing safety. The complexity of this assessment process is also reflected in the two primary orientations of situation influences. Some aspects of the approach situation directly affect the LSO's ability to perceive relevant approach stimuli. Examples of this are low visibility environmental conditions and carrier deck motion. Other factors affect the LSO indirectly by causing an increase in pilot workload. Examples of this are aircraft malfunctions and crosswind conditions.

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[8] See footnote 1, page 16.

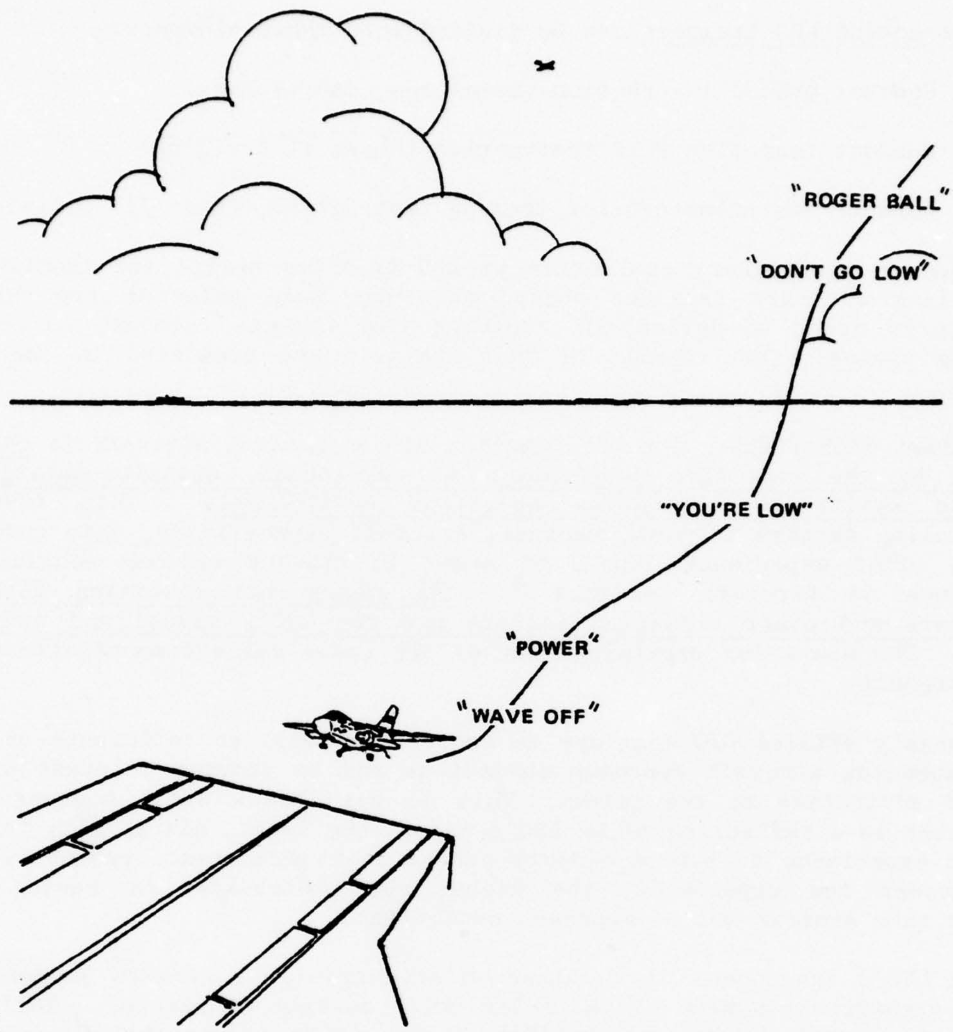


Figure 7. Typical Approach Resulting in Waveoff

Before looking more closely at specific LSO tasks and cues it is important to provide an overview of LSO interventions during a carrier approach. Figure 7 graphically depicts an approach profile and is annotated with LSO voice calls. In this approach the LSO accepted control with the call "Roger Ball" in the response to a pilot call. The aircraft starts with a high deviation. As the pilot corrects the deviation, the LSO perceives a potential deviation to below the glideslope and calls "don't go low." No correction is perceived to the LSO calls "you're low." Inadequate correction to this call results in a "Power" call. Insufficient response to this call results in a "waveoff" call by the LSO, terminating the approach. The "waveoff" call may have been influenced by either the LSO's dissatisfaction with the pilot's responsiveness or the proximity of the aircraft to a position from which the aircraft could not safely recover.

The view from the LSO workstation, called the "platform," is depicted in Figure 8. The basic visual cues within this view include the aircraft, the carrier deck outline, the horizon, the ship's wake and an accompanying ship called the plane guard destroyer. Figure 5 presented earlier depicts the approximate positioning of the LSO platform on the carrier.

LSO tasks basically involve the assessment of parameters or conditions during carrier landing activity and directing pilot actions resulting from his assessments. Subsequent paragraphs provide additional discussion of operational LSO tasks and cues. A listing of tasks is presented in Appendix A.

Assessment of Aircraft Approach. This functional element is comprised of two tasks, the assessment of aircraft approach parameters and the assessment of aircraft status. The aircraft approach parameters are the primary inputs to the LSO decision-making process. The LSO responses (signals to the pilot) are based on these parameters and modified, based on other situational factors (addressed later). Some "snapshot" aircraft approach parameters of concern to the LSO include vertical and lateral positioning relative to the optimum flight path for approach, distance from touchdown, and aircraft pitch attitude. Some of the dynamic parameters include rates of positional change, pitch changes, acceleration, and engine thrust changes. The cues for this task are primarily visual and include positional reference of the aircraft or its lights to the horizon, the plane guard destroyer, the carrier deck, etc. Engine thrust changes are assessed, in the case of some aircraft, with both auditory and visual (smoke) cues. Job aids which provide support to the LSO include the Pilot Landing Aid Television (PLAT) for line-up indications and the SPN-42 radar data readouts for glideslope, line-up, and speed indications. Frequently, the controlling LSO receives information concerning aircraft line-up deviations from a backup LSO on the platform who monitors the PLAT. Line-up deviation is the most difficult parameter for the controlling LSO to perceive (or easiest to lose control of) when multiple parameter deviations exist.

Aircraft status considerations include type aircraft (F-14, A-7, etc.), configuration (wheels down, flap positions, etc.), fuel state, emergency/malfunction (engine failure, hydraulic system failure, etc.), and landing sub-system functions (APCS, DLC, etc.). Some of these are perceived from radio or ship intercom calls such as fuel state and an emergency. Significant personnel interaction for these assessments occurs with the Air Boss, CATCC, and Air Operations.

Assessment of Recovery Conditions. This element is comprised of three tasks: assessment of environmental conditions, assessment of the condition of landing aids, and assessment of operational factors. Environmental considerations of concern to the LSO include ambient light (day/dusk/night), visibility, carrier deck motion, wind over the deck, horizon, noise, etc. Landing aids which affect the carrier landing activities include the operability and angular settings of the lens (FLOLS), availability of approach aids (ACLS, TACAN, SPN-42), MOVLAS, and radio. Operational factors of interest to the LSO include whether deck preparations are ready for aircraft landing (clear vs. foul deck), availability of airborne tanker, geographical constraints, and plot skill/proficiency levels.

Figure 8. View from LSO Platform

Directing Pilot Actions. There are two methods by which the LSO communicates with the pilot. The primary method is the use of radio voice calls. Using common sets of phrases, the LSO provides information to the pilot which is either informative, precautionary or imperative in nature. The calls primarily provide information to the pilot concerning approach parameter deviations and actions he should take to correct existing or impending deviations. The LSO vocabulary (standard and non-standard phraseology) and related pilot responses are presented in Appendix D. Informative calls include "you're high/low", "you're fast/slow", or "you're lined up right/left." Precautionary calls include "check your lineup," "don't climb," or "don't settle." Imperative calls include "power," "attitude," "waveoff," and "right for lineup." In terms of aircraft range from touchdown, the informative and precautionary calls are usually used early in the approach and the imperative calls in the latter portion of the approach. The other method of LSO communication to the pilot involves the activation of equipment which provides visual signals. These include (1) the waveoff lights (signalling the pilot to discontinue approach), (2) the cut lights (used during radio failure and EMCON/ZIPLIP conditions to acknowledge LSO control and indicate a low deviation), and (3) the MOVLAS (which manually provides glideslope position information). The MOVLAS is a backup system to the FLOLS. A skilled LSO frequently uses conversational communications to the pilot in unusual situations or as a way to minimize pilot apprehension in difficult situations.

Advising Superiors. LSO assessments of recovery situations lead to his recommendations concerning the feasibility, efficiency and safety of recovery operations. The LSO may recommend discontinuing landing operations due to weather problems or inoperability of landing aids. He may recommend that a specific aircraft be diverted to a shore base due to an aircraft malfunction or to pilot performance difficulties. His recommendations may be solicited or unsolicited. His primary interactions for this task are with the Air Officer ("Air Boss"), the individual responsible for controlling carrier launch and recovery activities, and with the Air Operations Officer ("Air Ops"), the individual who coordinates approach and departure activities.

LSO BEHAVIORAL OBJECTIVES

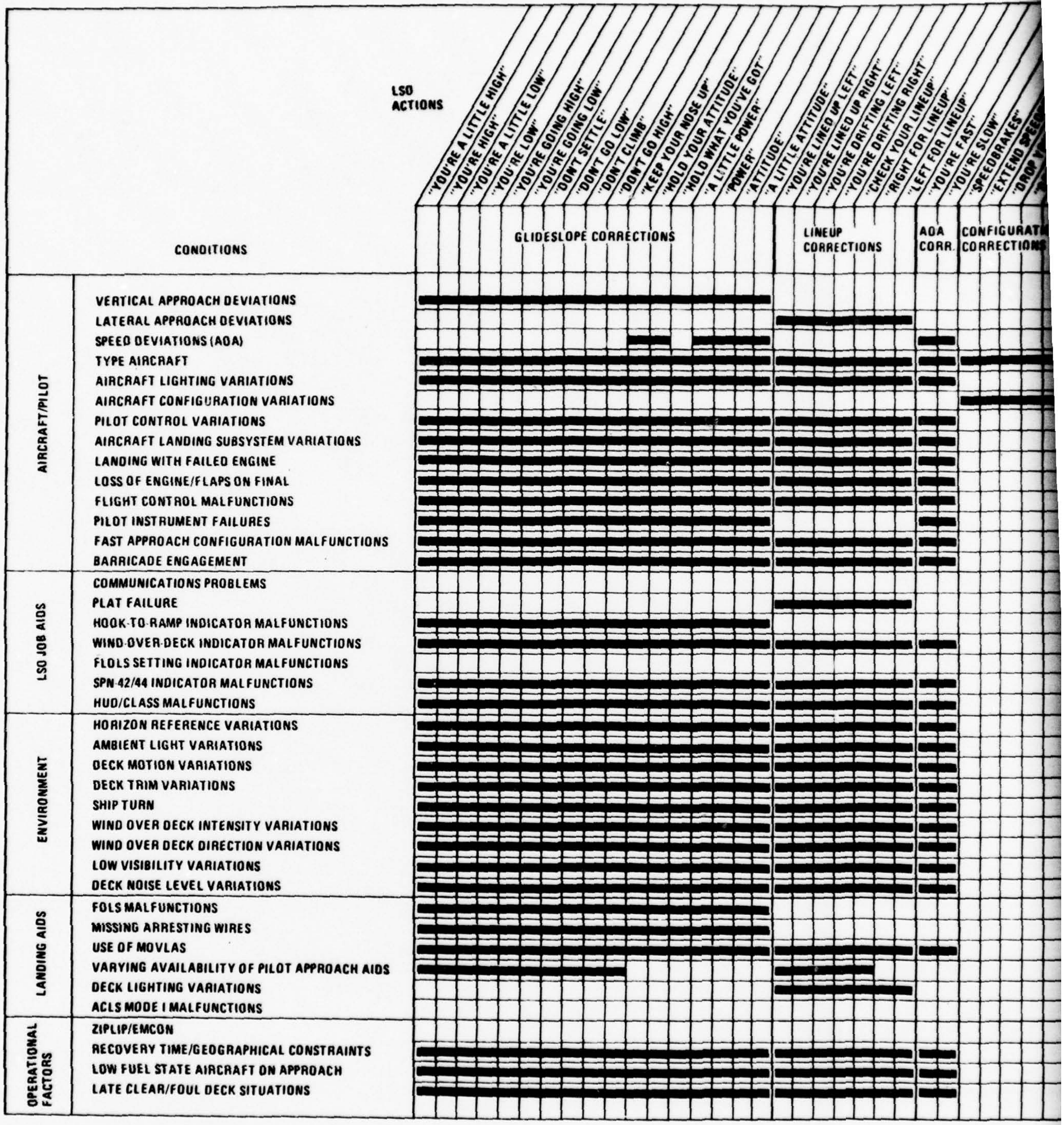
There was little difficulty in identifying candidate behaviors for an LSO training system. The LSO tasks in directing pilot actions (voice calls and control manipulations) are observable results of the LSO's perceptual and decision-making processes. These tasks are potentially measurable and reliable in an automated training system context, a controlled training environment.

The voice call behaviors selected during this study include only those described in LSO NATOPS. There are others (non-standard) which are used by qualified LSOs in the job environment that are not included in the behavioral objectives. These non-standard calls are merely different words for accomplishing the intent of the standard calls. Their absence is not based on a qualitative judgment of their job and training performance value. It is based on an impending Navy effort to consider modifications to the prescribed LSO phraseology. Both standard (prescribed by LSO NATOPS) and non-standard phrases are presented in Appendix D. Modifications to the standard phraseology can be easily incorporated into the training requirements specified in this study without disturbing the training applications context of an automated LSO training system.

Prior doubts concerning the absence of objective performance standards are undergoing resolution in studies of LSO behavior conducted by Human Performance Research, Inc. (HPRI). The HPRI effort has produced a preliminary framework of LSO decision-making logic which includes the identification of relevant aircraft approach parameters associated with acceptable LSO behavior. Future empirical studies will focus on validation of the HPRI behavioral model and will also provide guidance in the identification of LSO actions which are equivalent (such as "don't settle" and "don't go low"). This model of job performance will serve as a goal for LSO trainee performance. The primary measures of performance based on the model are expected to be timeliness and accuracy of LSO action.

The conditions elements of LSO behavioral objectives are based on the various situational factors which apparently influence the LSO perceptual and decision-making processes. The experience criteria for Wing LSO designation (multiple aircraft types, all weather and deck conditions, etc.) were established as goals for incorporation into the learning environment of an automated LSO training system. This goal is also compatible with the desired proficiency training role of the system. Therefore, the candidate behavioral objectives included in this report cover an extensive range of conditions found in the LSO operating environment. Actual implementation of objectives from among these candidates will possibly be limited by technological limitations (inability to simulate the real world) and training effectiveness constraints (such as performance evaluation difficulties).

A matrix correlating the action elements to the conditions elements was devised, due to the large number (approximately 900), and to the tentative nature of the behavioral objectives. Figure 9 presents the matrix of LSO behavioral objectives. Across the top of the matrix are the action elements of the objectives. The left column lists the conditions elements. The marked intersections indicate the relevance of a specific condition to the successful demonstration of a specific action. For organizational reference, the matrix also indicates groupings of actions (e.g., glideslope corrections, lineup corrections, etc.) and conditions (e.g., aircraft/pilot variations, LSO job aid variations, etc.). Although the action elements are very distinctive, the conditions elements often indicate a range of variation. For example, vertical approach deviations include high and low deviations (amount), as well as varied rates of the deviations. Communications problems include aircraft radio failure, LSO radio failure, and intermittent communications situations (prior to approach as well as failures occurring during the approach). Ambient light variations include day, dusk, and night. These are only a few of the detailed variations available for inclusion in the matrix. The uncertainties of selecting from among these candidate objectives (for implementation in an LSO Training System) preclude the need for such level of detail at this time. Each of the groupings and some sample action-condition correlations are described in the paragraphs which follow.


LSO ACTIONS
"YOU'RE A LITTLE HIGH"
"YOU'RE HIGH"
"YOU'RE A LITTLE LOW"
"YOU'RE LOW"
"YOU'RE GOING HIGH"
"YOU'RE GOING LOW"
"DON'T SETTLE"
"DON'T GO LOW"
"DON'T CLIMB"
"DON'T GO HIGH"
"KEEP YOUR NOSE UP"
"HOLD YOUR ATTITUDE"
"HOLD WHAT YOU'VE GOT"
"A LITTLE POWER"
"POWER"
"ATTITUDE"
"A LITTLE ATTITUDE"
"YOU'RE LINED UP LEFT"
"YOU'RE LINED UP RIGHT"
"YOU'RE DRIFTING LEFT"
"YOU'RE DRIFTING RIGHT"
"CHECK YOUR LINEUP"
"RIGHT FOR LINEUP"
"LEFT FOR LINEUP"
"YOU'RE FAST"
"YOU'RE SLOW"
"SPEEDBRAKES"
CONDITIONS
GLIDESLOPE CORRECTIONS
LINEUP CORRECTIONS
AOA CORR.
AIRCRAFT/PILOT
VERTICAL APPROACH DEVIATIONS
LATERAL APPROACH DEVIATIONS
SPEED DEVIATIONS (AOA)
TYPE AIRCRAFT
AIRCRAFT LIGHTING VARIATIONS
AIRCRAFT CONFIGURATION VARIATIONS
PILOT CONTROL VARIATIONS
AIRCRAFT LANDING SUBSYSTEM VARIATIONS
LANDING WITH FAILED ENGINE
LOSS OF ENGINE/FLAPS ON FINAL
FLIGHT CONTROL MALFUNCTIONS
PILOT INSTRUMENT FAILURES
FAST APPROACH CONFIGURATION MALFUNCTIONS
BARRICADE ENGAGEMENT
LSO JOB AIDS
COMMUNICATIONS PROBLEMS
PLAT FAILURE
HOOK-TO-RAMP INDICATOR MALFUNCTIONS
WIND-OVER-DECK INDICATOR MALFUNCTIONS
FLOLS SETTING INDICATOR MALFUNCTIONS
SPN 42/44 INDICATOR MALFUNCTIONS
HUD/CLASS MALFUNCTIONS
ENVIRONMENT
HORIZON REFERENCE VARIATIONS
AMBIENT LIGHT VARIATIONS
DECK MOTION VARIATIONS
DECK TRIM VARIATIONS
SHIP TURN
WIND OVER DECK INTENSITY VARIATIONS
WIND OVER DECK DIRECTION VARIATIONS
LOW VISIBILITY VARIATIONS
DECK NOISE LEVEL VARIATIONS
LANDING AIDS
FOLS MALFUNCTIONS
MISSING ARRESTING WIRES
USE OF MOVLAS
VARYING AVAILABILITY OF PILOT APPROACH AIDS
DECK LIGHTING VARIATIONS
ACLS MODE I MALFUNCTIONS
OPERATIONAL FACTORS
ZIPLIP/EMCON
RECOVERY TIME/GEOGRAPHICAL CONSTRAINTS
LOW FUEL STATE AIRCRAFT ON APPROACH
LATE CLEAR/FOUL DECK SITUATIONS

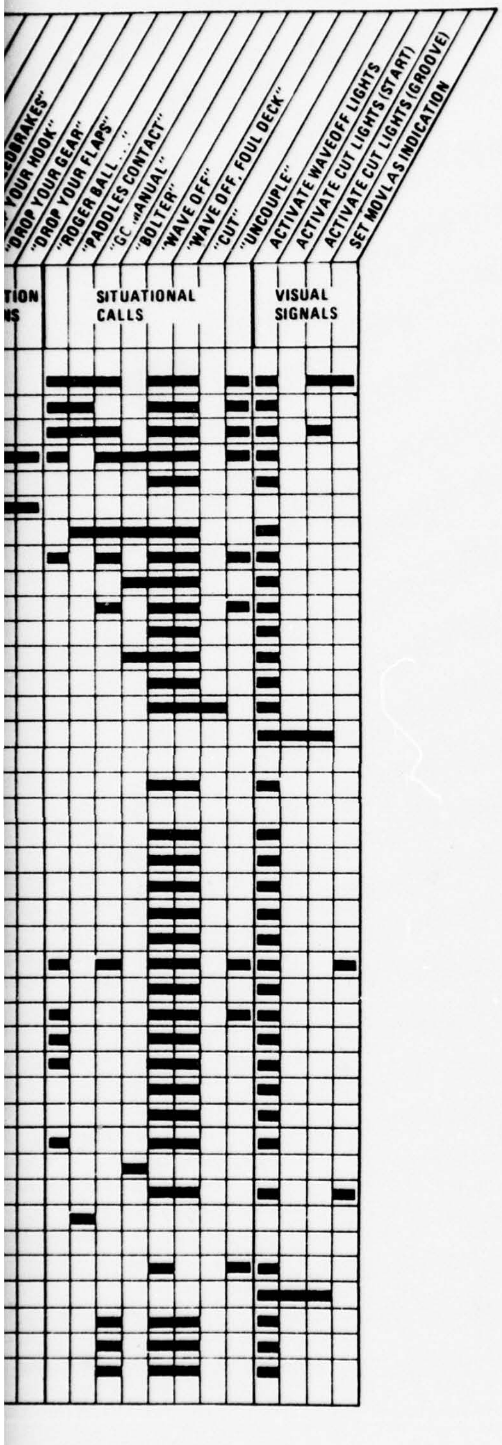


Figure 9. LSO Behavioral Objectives Matrix

LSO ACTIONS.

a. Glideslope correction calls include such phrases as "you're high/low," and "power." These are indicative of trainee ability to perceive vertical (glideslope) deviations, determine the need for LSO assistance (based on situation conditions) and to respond accordingly.

b. Lineup correction calls include such phrases as "check your lineup" and "right/left for lineup." These are indicative of trainee ability to perceive lateral (lineup) deviations, determine the need for LSO assistance (based on situation conditions) and to respond accordingly.

c. AOA/Speed correction calls include "you're fast/slow." These are indicative of trainee ability to perceive speed deviations (in terms of AOA indications as described earlier in the report), determine the need for LSO assistance (based on situation conditions) and to respond accordingly.

d. Configuration calls include such phrases as "speedbrakes," "drop your hook," and "drop your flaps." These are indicative of trainee ability to recognize variations (usually deviations) in aircraft configuration.

e. Situation calls include such phrases as "Roger Ball," "Paddles Contact," "Waveoff" and "Uncouple." The most critical action element in this grouping is the "waveoff" command which is indicative of trainee ability to perceive and evaluate aircraft approach or situational conditions relevant to safe landing criteria and to respond accordingly.

f. Visual signals relevant to trainee learning include activation of waveoff and cut lights on the FLOLS and manipulation of the MOVLAS. These signals correspond to some of the LSO voice calls but are primarily used as backup communications tools.

CONDITIONS.

a. Aircraft and pilot variations for presentation to the trainee include aircraft positional deviations (vertical and lateral), aircraft types (F-14, A-7, A-6, etc.), pilot responsiveness (skilled pilot, pilot exhibiting only lineup control difficulties, CQ pilot exhibiting unpredictability, etc.) and aircraft malfunctions/emergencies. Aircraft approach parameter variations (glideslope, lineup, speed) alone provide conditions for trainee demonstration of basic perceptual, decision-making and response skills. Other variations present more advanced learning situations for the trainee.

b. LSO job aid variations are concerned with the availability and operability of such items as the PLAT, WOD indicator, and the SPN-42 indicators.

c. Environmental variations include the horizon (well defined or nonexistent), ambient light (day, night), wind direction and speed, deck motion, low visibility, etc. Degradation of environmental conditions provides the trainee with various perceptual complexities.

d. Landing aid variations are conditions affecting pilot control effectiveness during approach (thus influencing LSO trainee performance difficulties). Included are such items as FLOLS malfunctions (meatball stabilization, lens failure), loss of pilot approach aids (TACAN, SPN-42 radar), deck lighting, etc.

e. Operational factors of concern to LSO training include situations which emphasize landing efficiency (low fuel state aircraft, impending weather difficulties, geographical ship maneuvering constraints) and EMCON/ ZIPLIP exercises (requiring minimal radio communications).

SUMMARY

In the early portions of this study, problems in LSO training were analyzed and solution alternatives evaluated. This established the conceptual validity of using an LSO training system as a vehicle for reducing calendar time for LSO training and for enhancing LSO skill levels. LSO tasks and cues were analyzed to establish a job performance basis for identifying the candidate training requirements for an LSO training system. The training requirements derived from job analysis data took the form of behavioral objectives based on observable and measurable LSO trainee actions which were conceptually compatible with the state of training and simulation technology. The next section of this report will present the results of investigations and analyses of training implementation strategies and practical applications.

SECTION IV

AUTO-ADAPTIVE LSO TRAINING

INTRODUCTION

On the basis of existing LSO training deficiencies and the job performance based training requirements described earlier, this section describes a context for the implementation of an LSO training system. This section will address global LSO training system concepts, the applicability of auto-adaptive training concepts to LSO training, and the factors influencing training system implementation.

LSO TRAINING SYSTEM CONCEPT

A measurable goal for the solution of LSO training problems is to enable reduction of the calendar time for LSO training. A qualitative goal is the development of a tool with the capability to enhance the acquisition of higher LSO skill levels and the maintenance of LSO proficiency. Achievement of these goals requires impact on both the efficiency and effectiveness of the LSO trainee learning process. These serve as the basis for establishing LSO training system functional concepts.

Types of learning relevant to LSO training are important considerations for the establishment of training system concepts. The apparent types of learning which must be promoted by an LSO training system include skill acquisition (perceptual, decision-making and response) and skill maintenance (proficiency). Support of perceptual learning implies the presentation and instructional control of relevant cues (cues having some degree of similarity to reality). The decision-making process and resultant responses evident in LSO job performance are time critical. Therefore, support of this learning implies the need for real-time trainee interaction with his environment. Support of the skill maintenance for a qualified LSO implies the need for significant environmental realism. Trainee performance evaluation is another important functional consideration for an LSO training system. The need for reliable determination of the trainee's achievement of learning (behavioral) objectives calls for objective performance measurement. The goal of training efficiency is another functional consideration. Implementation of adaptive training concepts is an appropriate functional requirement to support this goal.

The functional considerations described above provide strong rationale for an LSO training system which is automated and adaptive. Automated as stated here implies a closed-loop system. In functional terms, this calls for automation of the pilot/aircraft element and provisions for interactive control of that element by the trainee. Other automated characteristics include control of the learning environment (the presentation of cues and situations) by automated adaptive logic and automated performance measurement. The environmental realism requirements for LSO skill acquisition have yet to be determined. Artificial or exaggerated cues may prove adequate for supporting significant training transfer. However, there appears to be a strong requirement for significant environmental realism to support proficiency training. User (LSO) acceptance could be a significant influence on the degree of realism required for training system effectiveness.

There are existing training system applications which offer additional support to the feasibility of an automated, adaptive LSO training system concept. The Automated Adaptive Flight Training System (AAFTS) application on an F-4 flight trainer has demonstrated the effectiveness of limited automation of performance measurement and adaptive training control for complex operational and tactical flight tasks. An experimental Ground Controlled Approach (GCA) training system, using an automated speech understanding system (SUS), automated voice generation and automated adaptive logic, has demonstrated the feasibility and potential benefits of a closed loop, interactive adaptive training system. The results of training transfer studies concerned with air combat maneuvering (ACM) training in flight simulators having wide angled visual systems, verify the potential for effective perceptual and decision-making skill acquisition in a simulated visual environment.

Subsequent portions of this report will explore auto-adaptive LSO training to establish a conceptual framework for the functional architecture of an LSO training system.

AUTO-ADAPTIVE LSO TRAINING CONCEPTS

From a training perspective, an automated adaptive system concept appears to have great potential for training effectiveness. The functional adaptive components define the method by which the knowledge will be conveyed and skill development encouraged by the system. According to Atkinson (1976),[1] adaptive training involves varying the difficulty of the to-be-learned task as a function of the performance of the student. In addition, the adaptive system itself adapts as the number of students using the system increases and their performance records identify possible improvements in the initial instructional strategies. An adaptive training system has three components, (1) a set of instructional alternatives, (2) a performance evaluation system, and (3) an adaptive logic (Chatfield and Gidcumb, 1977).[2] The instructional alternatives for the LSO training system consist of a set of problems or tasks that are specified by the behavioral or learning

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1 Atkinson, R.C., Adaptive instructional systems: some attempts to optimize the learning process, Cognition and Instruction, ed. D. Klahr (New York: Halstead Press, 1976), pp. 81-108.

2 Chatfield, Douglas C. and Gidcumb, Charles F., Optimization techniques for automated adaptive training systems, Technical Report NAVTRAEQUIPCEN 77-M-0575, 1977.

objectives listing. The perceptual, cognitive, verbal, and motor skills which the prospective LSO must eventually demonstrate are delineated in the task listing (Appendix A) and the learning objectives matrix. The performance evaluation or measurement component scores the trainee's performance and feeds the information to the adaptive logic. The adaptive logic is composed of a set of decision rules that specify which instructional alternative is appropriate to the student's ability. In the discussion that follows, each of these three adaptive components will be discussed in terms of its role in an adaptive LSO training system.

INSTRUCTIONAL ALTERNATIVES. The instructional alternatives for the LSO training system are the exercises and scenarios presented for the student to control, the exercises and scenarios which the system controls as examples for the student, the various types of feedback and the introductions to the various topics to be learned. The identification of the topics, exercises, and scenarios is based upon task analysis and definition of behavioral/learning objectives. Tasks and learning objectives are discussed in Section III.

In addition to the identification of the instructional alternatives, these alternatives have been subjectively organized into a sequence reflecting task difficulty, frequency with which the task occurs in the operational environment, and the criticality of the task to the development of adequate waving (aircraft control) skills for a particular level of competency. This sequence represents an initial draft of the instructional syllabus. Given that the system will be adaptive in the sense of Atkinson's definition, the self-modifying requirement will be satisfied by allowing the system to rearrange the sequencing of the syllabus based upon the data collected from the students that are trained. Basically, this procedure is an optimization process and will be discussed further in the subsection concerning the adaptive logic.

The focus of our discussion for the remainder of this subsection is the initial syllabus and the rationale which was incorporated into its design. Basically, the syllabus functions as an organizational device for introducing the new student to the LSO task and systematically presenting this student with the information needed to ultimately perform the LSO task at the level of Wing LSO. The automated training system is not intended to provide the fleet with Wing designated LSOs without requiring that each trainee be given a sufficient amount of on-the-job training aboard ship. Therefore, the syllabus is designed to assist and direct the student in developing the basic waving skills and to expose him to most of the situations he will encounter in the fleet. The later portions of the syllabus are specified as enrichment exercises which are designed to present unusual situations designed primarily for the competent LSO who needs to retain and expand his waving competencies.

The syllabus is designed to support the overall mission of LSO training, namely, to reduce the number of calendar days and the amount of on-the-job training required for the trainee to attain a level of waving skills that makes him a productive LSO. In designing the instructional syllabus there were a number of assumptions and considerations which influenced the resultant adaptive training design.

The principles which guided the syllabus development are:

a. The primary skills that the prospective LSO must develop are perceptual, decision making, and response skills.

b. The most efficient method for developing these skills is in a linear, serial manner. That is, the skills developed during the initial phases of training are necessary precursors of the development of more sophisticated skills that appear later in training.

c. The complex LSO task can be broken into simple parts for pedagogical purposes but sufficient training time must be allowed following the part training for synthesis of the complex task.

d. Practice is a key in the development of all skills, and perceptual and cognitive skills are not exceptions.

e. The order of topic presentation requires the learner to exercise existing skills while acquiring a new skill.

f. Individual differences between students require that the training system be responsive to the individual student in terms of presentation rate, manner of presentation, amount, difficulty and complexity of material presented.

g. The adaptive learning system should not allow the student to practice incorrect behaviors. Additionally, the system must keep pace with the learner by presenting material that challenges the student without overtaxing or underutilizing his abilities.

h. The student must understand exactly what is expected of him by the training system and what he can expect from the training system.

A significant concern in the development of all aspects of the system, and particularly the syllabus, has been user acceptance. Sophisticated training techniques are not enough to ensure an effective training system. The student's motivation is a critical ingredient in his learning success. Therefore, in addition to inspiring the student through challenging problems, the system must avoid undermining his motivation by recalcitrance, particularly in the area of automated speech understanding. For this reason accurate and reliable speech understanding is a critical element of auto-adaptive LSO training.

In general, user acceptance will be secured by good feedback. When the student performs well, he will be commended. If his performance is imperfect, feedback will be available detailing the precise nature of the errors and corrective measures will be provided. Thus, there will be no mystery surrounding the system's evaluations, and positive suggestions for improvement will be available.

The student is not the only user who must be considered when designing the syllabus. The instructor and the LSO community in general are also important users of the system. The individual instructor will accept the system only if he is given an adequate amount of information regarding how the system trains, what type of input he can make, and what type of feedback he can expect from the system. The overall learning situation must be structured such that the instructor feels he is in control of the training process and that the system is merely an extension of his instructional approach, an instructional aid. While the system will take over the nuts and bolts of training, the instructor will function as the instructional manager, providing insight into the more abstract training problems that the system will not be equipped to address.

The skeletal structure of the syllabus is described topically and conditionally in Table 2. The syllabus is designed in a modular form with the training program organized into blocks of training. The blocks of training are designed to be sequentially taught. The entry level skills of the student will determine where the student begins in the sequence. Each block is comprised of a series of levels of achievement. Each level of achievement is concerned with the development of a specific skill or the presentation of a certain type of situation. The levels of achievement are hierarchical in function, especially where skill development is concerned. The initial level is usually an introduction to give the student a perspective of exactly what he will learn in the training block. Each level thereafter concentrates on a specific skill or type of situation, building upon and incorporating knowledge and skills learned in previous levels.

The training functions are defined even further with each level of achievement composed of six phases of training. The first phase is an introductory demonstration phase where the specific skill or situation is explained in detail. In each case the system and the student are required to interact so that the system can validate the student's voice patterns and the student can learn the radio terminology and begin integrating the cognitive aspects of the skill. Phase two is a practice phase where the system simulates an instructor closely monitoring a student's performance, stopping the approach when an error is made and explaining student performance problems. In phase three the student is allowed to practice integral runs without system intervention. The student will be given the option of instructional feedback during replays of the approaches. The replay option will be selectable in any of three forms. The first form is a straight replay of the approach where no system annotation is supplied, the student analyzing the approach and looking for his own errors. The second option will be a replay where the system makes constructive comments on the student's performance during the approach. The third option is an errors-only replay where the system replays and makes comments on the errors that the student made during the approach.

The phases of training are sequential in proceeding from day approaches in phases two and three to night approaches during phases four and five. Phase four corresponds to phase two in function, however it also includes an introduction and explanation of the differing aspects inherent in night approaches. Phase five corresponds to phase three. Phase six is a composite phase where both day and night approaches occur and the student is expected to demonstrate his capacity to handle both efficiently. There may

TABLE 2. SYLLABUS STRUCTURE

Block One — Introduction and Orientation

Level one — Introduction and overview of the training system
Level two — Introduction to the visual system
Level three — Introduction to automatic speech understanding
Level four — Introduction to the simulated workstation and job aids
Level five — Model LSO
  a. Performance measurement
  b. The concepts of "call window", "wave-off window", "call envelope", and "safety envelope"
Level six — The adaptive nature of the training system
  a. Based on individual performance
  b. Blocks of training
  c. Levels of achievement
  d. Training phases within each level

Block Two

Level one — Introduction and overview of Block Two, including:
  a. Radio terminology (R/T) to be used
  b. Wave-off envelope and window
  c. Call envelope and window
  d. Wave-off calls
Level two — Glideslope deviations and calls
Level three — Line up deviations and calls
Level four — Glideslope and line up
Level five — Glideslope and Angle of Attack (AOA)
Level six — Glideslope, lineup and angle of attack

Block Three

Expansion of the basic LSO skills to include a dynamic call envelope and precautionary and imperative calls

Level one — Overview of the training block
Level two — Introduction to range and the precautionary calls that are associated with "start" and "in the middle"
Level three — Introduction to imperative calls
Level four — Introduction to changes in rate of deviations — glideslope
Level five — Introduction to changes in rate of deviations — lineup
Level six — Introduction to changes in rate of composite deviations

Block Four

Level one — Overview of situations to be encountered and recovery conditions in this training block. Conditions:
  a. Dark night recovery
  b. Multiple aircraft recovery
  c. Aircraft all the same type
— Introduction to selected job aids and equipment
  a. Lens setting indicator
  b. Foul deck/clear deck indicator
  c. Wind over deck indicator

TABLE 2. SYLLABUS STRUCTURE (Cont)

Block Four (Cont)

d. PLAT
e. SPN 44
f. SPN 42

Level two — Use the new job aid equipment

Level three — Selected factors that affect the quality of the aircraft's approach:
a. Gross start deviations
b. Bad CCA starts
c. Deviations during the handoff
d. Unusual pilot responses

Level four — Common situations aboard the aircraft that affect the LSO's performance or the approach itself.
a. Incorrect aircraft configuration
b. Aircraft lighting problems
c. Crosswinds (moderate)

Level five — Frequently occurring situations in which the pilot loses visual feedback
a. Pilot calls "Clara" at the start
b. Pilot loses the ball during the pass

Level six — Common deck conditions that impact the recovery
a. Foul deck/clear deck
b. Slow retracting of a wire during an approach (delays clearing of the deck)
c. Activity in landing area during an approach
d. Noise on deck

Level seven — Common radio problems
a. No radio (NORDO)
b. CATCC fails to change LSO radio frequency
c. Loss occurs on final with no warning
d. Intermittent transmissions

Level eight — Aircraft flying automatic approaches
a. Direct Lift Control (DLC)
b. Automatic Power Compensation (APC)
c. ACLS
d. Malfunctions of these systems

Level nine — Job aid malfunctions
a. Lens setting indicator inoperative
b. Wind over the deck indicator inoperative
c. Wind over the deck indicator inaccurate
d. PLAT inoperative
e. SPN 44 indicator inoperative
f. SPN 42 indicator inoperative

TABLE 2. SYLLABUS STRUCTURE (Cont)

Block Five

Level one — Overview of situations to be encountered and recovery conditions presented in this training block
- a. Dark night recovery
- b. Multiple aircraft recovery
- c. Aircraft all of the same type
- d. Full range of pilot skills
- e. Moving deck

— Introduction to selected job aids and equipment
- a. Hook to ramp indicator
- b. MOVLAS

Level two — Common situations that will affect the pilot's performance for which the LSO must compensate
- a. Precision radar inoperative
- b. Flood lighting inoperative
- c. Loss of deck lighting

Level three — Decrement in LSO visual cues that increase recovery difficulty
- a. Horizon problems

Level four — Wind conditions that affect the recovery
- a. Crosswind (significant)
- b. Excessive wind over the deck
- c. Minimum wind over the deck

Level five — Ship conditions that impact LSO performance
- a. Deck movement
- b. Introduce the hook to ramp indicator
- c. Steady deck, slight motion (train LSO to use MOVLAS)
- d. Significant deck movement — use MOVLAS
- e. Steady out-of-trim deck
- f. Ship turning
- g. Hook to ramp indicator inoperative — excessive deck movement

Level six — Emergency situations and techniques
- a. Aircraft emergency — single engine
- b. Barricade recovery

Block Six

Level one — Overview of situations to be encountered and recovery conditions presented in this training block
- a. All conditions that have been presented previously may be presented in this block if the LSO's waving technique is affected differentially by the recovery situation as a function of the type of aircraft being waved.
- b. Types of aircraft to be introduced and their flight characteristics (F14, A6, S3, E2, F4, A7, F18, EA6)

Level two — Multiple aircraft recovery single type of aircraft in recovery vary aircraft type

Level three — Multiple aircraft recovery multiple aircraft types in recovery

TABLE 2. SYLLABUS STRUCTURE (Cont)

<u>Block Seven</u>

Level one — Overview of situations to be encountered and recovery conditions presented in this training block. Conditions:
- a. All conditions encountered in previous blocks are candidates for implementation in this block

— Introduction to selected job aids and equipment
- a. HUD
- b. CLASS

Level two — Practice using HUD/CLASS

Level three — Pilot experiences a visual problem with the lens
- a. Lens too bright or dim
- b. Loss of lens during approach (malfunction) LSO talkdown required
- c. Lens out of calibration
  - (1) results in a series of consistently high or low passes

Level four — Weather — low ceiling or cloud bank — aircraft breaks out inside 3/4 mile

Level five — Aircraft emergencies
- a. Aircraft loses an engine "in the groove"
- b. Aircraft with flap blowup "in the groove"
- c. Flight control problems

Level six — Job AID malfunctions
- a. Waveoff lights (pickle) inoperative
- b. Cut lights (pickle) inoperative
- c. HUD inoperative
- d. CLASS inoperative

<u>Block Eight</u>

Level one — Overview of situations to be encountered and recovery conditions presented in this training block. Conditions:
- a. All conditions encountered in previous blocks are candidates for implementation in this block

Level two — Conditions that affect the safety-efficiency trade-off
- a. Low fuel state
- b. Subsequent aircraft in pattern have low fuel state
- c. No tanker, long divert for bingo field
- d. Ship running out of sea room or running into weather (fogbank)

Level three — Aircraft malfunctions
- a. Weak hook downspring or dashpot
- b. Mode 1 ACLS malfunction

Level four — Pilot conditions that affect the recovery
- a. Night CQ — unproficient unpredictable pilot
- b. Pilot with record of poor approach tendencies — recent approaches, same recovery
- c. Pilot with vertigo

Level five — Decrement in LSO's visual cues that increase recovery difficulty
- a. Aircraft with only one light
- b. Aircraft with no (zero) lights

Level six — Job AIDS or recovery equipment malfunctions
- a. MOVLAS inoperative
- b. Missing wire(s)

be situations where a day operation or a night operation may not be applicable, for example, day operations when the training situation involves an inoperable wing light. In that instance, the phase associated with that condition will be deleted.

The initial syllabus was derived using subjective and basically unrefined techniques. The basic sequencing of tasks resulted from guidelines described above and the intuitive skills of LSO subject matter experts. Given this unempirical base, the desire for a more objective framework becomes apparent. However, a true empirical definition is not possible at this stage of development and will have to await the development of the prototype system. An empirical definition was approximated by allowing a number of experienced fleet LSOs to provide input into the syllabus design in an aposteriori manner. The inputs of these LSOs were, for the most part, favorable and no significant changes were required. Another question did surface, however, following these reviews and during consultation with the project Scientific Officer at NAVTRAEQUIPCEN. The problem concerned the effects of combining situational variables and assuming that the resultant interaction would be a linear function of the difficulty of the individual situations and not related in some more complex way. To assess this possibility a small study was conducted that required the several LSOs to rank order a variety of situations according to their subjective impressions of the difficulty of the proposed scenarios. A description of this study along with the results are given in Appendix F. The results of this study showed a high degree of correlation between the sequencing and combinations defined by the syllabus and rankings of the LSOs. Unfortunately, time and resources did not allow for extensive data collection and the results, as supportive as they might appear, cannot be taken as real support due to the inability to generalize when using what amounted to only two subjects. However, this analysis appears very adequate for this stage of syllabus design and is a potential tool for subsequent validation efforts.

PERFORMANCE EVALUATION. Performance evaluation is a process which drives the adaptive logic by providing information about the student's performance, thereby guiding the selection of the appropriate instructional alternatives by the adaptive logic. In LSO training, the adaptive system must address two separate, or nearly separate, problems. The first problem is the training of new LSOs from the very beginning to what will be a reasonable approximation of Wing LSO skills. The second problem the system must address deals with proficiency training. This problem arises when a trained LSO returns from deployment. Typically, there is a long layoff period during which the LSO has no opportunity to exercise his LSO skills, and his proficiency wanes. In this situation the training system could be used to present the LSO with training he needs to retain the skills he developed during carrier operations.

These two problems, learning and proficiency, present the system with an interesting performance evaluation problem. It seems very likely that the processing involved in maintaining a skilled perceptual/cognitive behavior, such as waving aircraft, will be quite different than the process involved in learning the skill in the first place. Learning of the skill may require a process of iterative synthesis (the development of several subskills or pseudoskills that eventually coalesce in a skill that allows the student to perform the LSO job tasks). Measuring the performance of the new trainee then requires identification of the subskills he must learn and the identification of a behavioral metric that is sensitive to the student's success in mastering that subskill. The proficiency problem, however, requires the identification of the skills of a proficient LSO (or at the very least those of an adequate LSO), and that the system is given the means to take measurements that will allow direct comparison to the proficiency model.

Both problems are separable to a degree. As an initial stepping-off point, though, both require at least a theoretical estimation of how performance measurement may be accomplished and the specification of a methodology for refining the modeling and measurement techniques as the system begins the self-modifying process identified with adaptive training systems.

The general approach taken in designing a performance evaluation technique is that the basic task of the LSO involves making voice calls which help the pilot keep the aircraft within a safe flight envelope. When the aircraft deviates outside of the envelope, the LSO is obliged to issue a waveoff. In the pages that follow, the boundaries of this safety envelope at any point in the approach will be referred to as the waveoff window. The non-linear structure of the envelope is reflected by the variability of the waveoff window as a function of approach conditions and situations. In order for the LSO to help the pilot keep the aircraft within the waveoff window, the LSO must make his correction calls early enough for both the pilot and aircraft to respond to the call without having the aircraft exceed the waveoff window. The call window is considerably more dynamic than the waveoff window, responding differentially to all conditions and situations that depart from ideal. The usual response of the call window is to become smaller (shrink) as the situation becomes more complicated. In order to more effectively train the basic waving skills, the initial portions of the syllabus will be designed to help the student develop an internal schema (Neisser 1976)[3] or concept of the wave-off and call windows (and associated discussions and responses) under ideal conditions. This basic task must be completely mastered before any of the complicating situations, so pervasive to the LSO environment, are introduced. The basic skills must be learned or overlearned to the point where they are performed in a very automatic way (LaBerge, 1975).[4] When the complicating situational factors are introduced, the student LSO will need to have his entire attention capacity available to solve new problems. Attention is viewed as a limited

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3 Neisser, Ulric, Cognition and Reality (San Francisco: W.H. Freeman and Co., 1976)

4 LaBerge, D., Acquisition of Automatic Processing in Perceptual and Associative Learning, Attention and Performance V, eds. P. Rabaitt and S. Pornic (London: Academic Press, 1975).

capacity processing system (Broadbent, 1958; Kahneman, 1973; Moray, (1969)[5 6 7] that can be overtaxed by complex tasks. When a task or series of tasks makes demands on the attentional system that exceeds its processing capacity, the student's performance will suffer and learning will be impeded. The cognitive apparatus has overcome this limited capacity problem by allowing well-learned (overlearned) skills to be accomplished in a more or less automatic or ballistic manner without involving the attentional mechanism.

This type of argument logically follows given the assumptions of contemporary information processing theory. In contrast, Gibson's (1966)[8] theory of information pickup leads to the same point by a different route, however. Gibson claims that the capacity problem is not a bottleneck within the cognitive apparatus, but merely a lack of sensitivity by the perceptual apparatus to the information that is available in the environment. When a student learns a perceptual task, what he is really doing is attuning his perceptual apparatus to the distinctive and invariant forms of information in the environment. Perceptual learning is then tied to affordance learning (learning what the environmental stimuli afford the perceiver). In the case of LSO training this involves learning the decision process and the response repertoire.

Given either orientation, the crucial point is that the student must be given enough practice to become automatic in processing, or in being attuned to the relevant information. By overtraining students in the basics of the LSO task, the objective is to avoid overtaxing the student's capabilities later in the syllabus. Complete automatizing of the tasks or attunement of the perceptual system may not be necessary so long as the demands on the attention system are sufficiently reduced or the perceptual system is nearly attuned to the proper stimulus, enabling the student to attain the capacity necessary to perform new skills. In summary, the syllabus will initially be designed to assure a relatively high degree of automaticity or perceptual attunement on the basics of LSO skills before the complicating situational factors are introduced. In the pages that follow, the topics of learning (or skill acquisition) and proficiency will be addressed and discussed at a theoretical level indicating the appropriate performance metric where appropriate.

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5 Broadbent, D.E., Perception and Communication (London: Pergamon Press, 1958).

6 Kahneman, Daniel, Attention and Effort (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1973).

7 Moray, Neville, Attention: selective processes in vision and hearing (London: Hutchinson Educational, LTD., 1969).

8 Gibson, James J., The Senses Considered as Perceptual Systems Boston: Houghton Mifflin Co., 1966).

a. Learning (Skill Acquisition). The problem of initially learning the LSO task may require the system to introduce a variety of artificial tasks and situations. One process to be identified is the process of cue selection or differentiation that the learner goes through. It is important to identify the critical cues or distinctive features of each scenario or situation which the student must wave. It is anticipated that the learning situation will entail a process of perceptual learning, either to associate (code) particular stimuli or to extract relevant information from the optical array. It seems likely that in a complex situation, such as the LSO environment, the association of stimuli or the identification of distinctive features requires a series of approximations to the skill level of a proficient LSO. It may not be just a matter of pointing out to the student the relevant cues or features (if they can indeed be identified). There may be a series of steps that each student must go through in order to arrive at the desired skill. The process of perceptual learning has been described by LaBerge (1976)[9] as a three stage learning process. The three stages are feature discovery, coding, and automatic coding. The LSO training system must address each stage separately and provide for a performance measure that reflects each stage independently. The first stage, FEATURE DETECTION, involves sensitizing the perceptual system to those aspects or features of the display which distinguish one pattern from another, a process labeled dissociation by John Locke and differentiation by E.J. Gibson (1969).[10] The term, feature, is related to the notion of a value of dimension. The perception of a feature implies that the student can contrast this feature with other stimuli. The relation by which features are contrasted is termed a dimension of the stimulus (Garner, 1974)[11] and the properties of a stimulus depend upon the properties of the sets of stimuli of which it is a member. It appears that the discovery of features or dimensions hinges upon experience with differences between stimuli. In the LSO training system it is suggested that pairs of the visual approach scenarios be presented simultaneously and the student be required to make same-different judgments. The goal will be to demonstrate that the student can isolate the critical feature of a display when all features are held constant except the one to be discovered.

It is a rare pattern that can be identified on the basis of a single feature, and most scenarios will require the discovery of several features. Merely discovering the features of a pattern is not sufficient to identify it uniquely. In the LSO environment the identification of an aircraft that is right of course, may require that the student discover a number of features in a particular arrangement or order. The arrangement or ordering of the group of features can be thought of as "combination information."

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[9] LaBerge, D., Perceptual Learning and Attention, Handbook of Learning and Cognition, ed. W.K. Estes, Vol. 4, 1976.

[10] Gibson, Eleanor J., Principles of Perceptual Learning and Development (New York: Appleton-Century-Crofts, 1969).

[11] Garner, Wendell R., The Processing of Information and Structure. (New York: John Wiler & Sons, Inc., 1974).

It is the detection of this "combination information" and the acquisition of a memory code that includes the features and "combination information" that comprise the second stage of perceptual learning, CODING. The metric used to assess coding is an identification task where the student is presented with a display and required to identify the position of the aircraft (make the appropriate call).

The final stage of perceptual learning involves AUTOMATIC CODING of the features and the combination information. During the coding stage of perceptual learning, a considerable amount of attention is required to scan the features, pick up "combination information" and then integrate these features into a code. With continued practice the requirement for attention decreases and the code begins to operate automatically. The appropriate metric for automatic processing involves careful control of the momentary deployment of the student's attention and the use of reaction time to assess the efficiency of the processing.

The discussion above pertains primarily to perceptual learning and secondarily to response learning as a part of the coding stage. There remains one hypothesized learning component to be discussed, namely the learning of decision strategies. Learning decision strategies involves the development of an internal decision logic or process which takes perceptual information and manipulates it in a particular way ultimately resulting in the timely and expeditious selection of an appropriate response. The decision strategy component can be thought of as a cognitive structure through which information must pass and be acted upon in order for the student to select the appropriate response. This characterization of decision strategies as an intermediary stage of cognitive processing is consistent with a contemporary information processing view of mental events. Other more parsimonious theories of behavior and cognition, for example Gibson's (1966)[12] theory of information pickup and Neisser's (1976)[13] schemata theory of cognition, ascribe the decision strategy type processes to the earlier more perceptual types of processing. For these theories, the decision strategy influences the pickup of information by specifying the form of that information in the environment. The specifying is done through the influences of affordances. The student learns through experience what a particular bit of information affords him in terms of his interaction with the environment. The theory of information pickup may be contrasted with the information processing theory through an analogy with computer programming. The theory of information processing seeks to determine how information is handled or manipulated just as the programmer's instructions or logic manipulate information in the computer. The theory of information pickup on the other hand is concerned with the extraction of information from the environment and is similar in function to the formats of the computer program.

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[12] See footnote 8 p. 50.

[13] See footnote 3 p. 49.

Implementation of one or the other of these theories would require the training system to engage in very different forms of training. The information processing view would allow the system to train decision making as a process entirely separate from perceptual learning and response learning. Therefore the performance measures that reflect decision strategies would be expected to be separate and independent of the other learning tasks. The theory of information pickup on the other hand would consider learning decision strategies as a subtopic that would be addressed by the stages of perceptual learning discussed above.

b. Proficiency. The performance measurement aspect of proficiency maintenance is primarily a matter of specifying a model of acceptable or adequate LSO performance. The model will provide a baseline against which the competent LSO's performance can be compared. Initial attempts in this direction are being made by HPRI using behavioral modeling techniques. The model they supply will be further expanded and modified during the laboratory and prototype phases where a number of LSOs can be exposed to a controlled variety of waving situations. The data from these controlled scenarios will be used to verify the HPRI model and to experimentally determine the form of visual cues used by the experienced LSOs. The shaping of the proficiency model will be a continuous process of self-modification that the system undergoes. Perhaps the most important function of proficiency training will be assure the automaticity of all aspects of LSO waving behavior.

ADAPTIVE LOGIC. The adaptive logic functions as the integrator of an adaptive system bridging the gulf between performance evaluation and instructional alternatives. Performance evaluation provides the data which the adaptive logic uses to guide its selection of the appropriate instructional alternative. The data provides the adaptive logic with a means of assessing the learning state of the student or the proficiency state of the competent LSO. A basic element in the functioning of the adaptive logic is the explicit or implicit learning (or performance) model. The adaptive logic for the LSO training system must address both types of training problems, skill acquisition and proficiency maintenance. In the discussion that follows both of these training aspects are addressed.

a. Skill Acquisition: The LSO's task is basically a perceptual/decision task and the process that takes place when a student acquires the LSO skills is a form of perceptual/decision learning. In the previous section on performance evaluation, three stages of perceptual learning were identified and the likely form of the performance metric in each case was discussed. In this section the goal will be to specify the relation of the performance metric to a learning model representative of each level of perceptual learning and then to discuss, in a general way, the optimization of the selection of instructional alternatives to minimize the time and effort the student must spend to acquire LSO skills. An additional goal will be to realistically maximize the skill level of the student at the conclusion of each block of training.

(1) Feature Discovery. It was suggested previously that feature discovery could be facilitated by presenting the student with simultaneous views of the object (aircraft), manipulating the display so that only a single feature or critical feature was different in the two views. This type of display is hypothesized to allow the student to isolate quickly the important feature and make his response based upon that feature. The response would result from a same/different decision where accuracy of the response is the overriding concern of the measurement system. This type of feature discovery learning has been described mathematically by J.A. Anderson (1974)[14] in terms of a neurophysiological model using the concepts such as vector traces and memory matrixes relating the isolation of distinctive features to sets of eigenvectors and system resonance. The implementation of this model in an applied training setting has not been tried and may be considered a risk area. However, if the implementation of this sort of model should prove difficult or unfeasible, there are a number of other models that should prove feasible. In fact, the best way to approach the modeling of the process is to identify the models that hold the most promise for describing the feature discovery process, specify how the models differ, generate different learning predictions from each model, and design an experiment to test the predictions. Once the model making the best prediction has been identified, that model can be used to drive the adaptive logic. In most cases the learning model will specify the performance metric and point to the appropriate model for optimizing the learning process through instructional alternative selection.

(2) Coding: The coding process is a recognition or identification process where the student learns to combine (unitize) the critical features (Estes, 1975)[15] or to extract the higher-order distinctive features (Gibson, 1969)[16] from the display. Again, the process needs to be described in terms of an explicit model of the learning process. The methodology outlined above for modeling the discovery of distinctive features can also be employed here. Subjectively, the most likely candidates for learning models are some form of an All-or-None Model, a Random-Trials Increments Model or Anderson's Neurophysiological filter type model. Care must be exercised in modeling the coding or unitizing process because of the confounding influence of the two separate learning processes that will be simultaneously occurring, the perceptual learning aspect and the response learning aspect.

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[14] Anderson, James A. What is a distinctive feature? Center for Neural Studies. Brown University, Technical Report 74-1, 1974.

[15] Estes, W.K., Memory, perception, and decision in letter identification, Information processing and cognition: The Loyola symposium, ed. R. Solso (New Jersey): Lawrence Erlbaum, 1975).

[16] See footnote 10, p. 51.

Optimization of the selection of instructional alternatives may be accomplished by utilizing Smallwood's (1970)[17] technique or a modification of that technique.

(3) Automatic Coding: Automatic coding represents the stage of perceptual learning for which there is the least empirical data and which may represent the largest risk area in the specification of an adequate mathematical model. LaBerge and his associates (LaBerge, 1973; LaBerge, Samuels and Petersen, 1973; Brownston, 1977)[18 19 20] have shown that automatic coding can be empirically demonstrated and that the control of attention is critical to this demonstration.

Model type descriptions for this process have for the most part been schema models (LaBerge and Samuels, 1974)[21] or verbal models (Blumenthal, 1977; Posner, 1975).[22 23] An attempt to mathematically model this process would be extremely fruitful, given the context of adaptive training and perceptual learning. An initial reaction to the modeling suggestion is to consider perceptual automaticity as similar to the automaticity process ascribed to psychomotor learning and modeled via an

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17 Smallwood, R.D., Optimal policy regions for computer-directed teaching systems, Computer-Assisted Instruction, Testing and Guidance, ed. W. Holtzman (New York: Harper and Row, 1970).

18 LaBerge, D.L., Attention and the measurement of perceptual learning, Memory and Cognition, 1, 1973, 268-276.

19 LaBerge, D.L., Samuels, S.J. and Petersen, R.J., Perceptual learning of artificial letters. Technical Report 6. Minnesota Reading Research Project, University of Minnesota, 1973.

20 Brownston, Lee S., Stimulus Structure and Perceptual Learning (unpublished PhD dissertation, University of Minnesota, 1977).

21 LaBerge, D.L.; Samuels, S.J., Toward a theory of automatic information processing in reading, Cognitive Psychology, 6, 1974, 293-323.

22 Blumenthal, Arthur L., The Process of Cognition (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1977).

23 Posner, M.I., Psychobiology of attention, Handbook of Psychobiology, eds. M.S. Gazzaniga and C. Blakemore (New York: Academic Press, 1975).

incremental learning model. Optimization of this process may perhaps be modeled using a technique similar to Wollmer's (1976)[24] or Chant and Atkinson's (1973).[25]

In general, the processes involved in perceptual learning need to be clearly identified and any confounding factors such as response learning must be controlled when arranging the training situation. Another confounding factor that must be addressed and parcelled out in the performance analysis is the effect of response bias (decision making). While this effect will effectively mask perceptual sensitivity, response bias is not a subject that should be controlled by balancing it out. Response bias should be addressed as a learning component that must be controlled through training in the same way that perceptual sensitivity is trained. The process of learning a response bias can be mathematically modeled and empirically manipulated through the prudent selection of instructional alternatives. Optimization techniques can also be applied to training this decision process.

b. Proficiency Training. Proficiency training requires the same sort of analysis as described above with regard to skill acquisition. The model of proficient performance is driven by input from the performance evaluation system and this model also guides the selection of instructional alternatives. The proficiency model is a description of proficient LSO behavior. The goal of the model is to maximize the exposure of the LSO to the various approach situations. The type of performance metric that is required is similar to the metric defined for determination of perceptual and decision making automaticity. As currently envisioned, the proficiency model should attempt to ensure automaticity on all facets of the LSO job. By maximizing automaticity, one is also maximizing the number of exposures to the various situations. The modification of a model such as Wollmer's 1976 model is the type of model that may best describe the task and the optimization of proficiency training. Chant and Atkinson (1973, 1978)[26 27] have modeled and discussed the optimization of the learning process when the instructional materials are interrelated, as most certainly the approach situations in the later portions of the syllabus are. Perhaps further investigation of the optimization literature will reveal a subjectively satisfactory set of candidate models, a synthesis of the existing models,

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24 Wollmer, R.D., Markov decision-model for computer aided instruction, Math Biosicience, 30, 1976, 213.

25 Chant, V.G. and Atkinson, R.C., Optimal allocation of instructional effort to interrelated learning strands, Journal of Mathematical Psychology, 10, (1973), 1-25.

26 Ibid.

27 Chant, Verne G. and Atkinson, Richard C., Application of loaning models and optimization theory to problems of instruction, Handbook of Learning and Cognitive Processes, Vol. 5, ed. W.K. Estes (Hillsdale, N.J.: Lawrence Erlbaum Associates, 1978).

or perhaps the generation of a new model will be called for. In any event, this is an area of development that needs to be pursued when the opportunity to collect data from fleet proficient LSOs becomes feasible.

IMPLEMENTATION CONSIDERATIONS

Uncertainty is inherent in the total implementation of auto-adaptive training concepts addressed earlier. However, recent advances in both the training and technical aspects of training technology provide justification for significant optimism concerning auto-adaptive LSO training. Establishment of ambitious implementation goals for an LSO training system is desirable as long as the optimism is tempered with reality. The purpose of this section of the report is to describe a desirable implementation context for system concepts addressed in earlier portions of this report and to review the uncertainties inherent in reaching this goal.

The desired role of the training system is to provide support for both learning and proficiency. The system would prepare a trainee for the OJT environment, supplement OJT, and provide a medium for proficiency maintenance. Trainee entry levels would be variable because of the adaptive nature of the system. The syllabus structure would allow for variable and identifiable exit levels from the system. The system would be conveniently located to optimize availability to the user, probably in the major areas supporting carrier aviation. The following section describes several aspects of a system implementation context including user entry level characteristics, syllabus progress and exit levels, potential system locations, and potential system value to LSO research.

SYSTEM IMPLEMENTATION CONTEXT. There are various syllabus entry level considerations for a potential LSO training system user: knowledge level, familiarity with the LSO operating environment, skill level, and time since skill application. The system itself should be designed to perform as an entry level assessment tool to insure a meaningful syllabus entry point for the user. There should be a purpose or an exit level goal for each system user. Given unlimited access to an unskilled user (defined as not having attained Wing LSO designation), a desirable training system syllabus exit level goal would be the accomplishment of training in all aspects of the capabilities required for Wing LSO designation. Flight operations commitments, non-LSO duties, system accessibility uncertainties, and other factors have the potential for disturbing the continuity of such a goal. It is also desirable to promote trainee motivation with intermediate levels of achievement. Therefore, it appears more realistic to identify intermediate syllabus exit level goals. There are obvious intermediate goals in terms of blocks and levels which are built into the syllabus described earlier. However, the primary intent here is to identify more global training goals in a practical context. Table 3 presents a synthesized continuum of entry level characteristics and the associated training purposes and exit level goals.

There are other training system uses worthy of mention. A system with the capability to simulate the actual LSO platform positioning on each aircraft carrier can be used to familiarize an LSO with the different visual

TABLE 3. SYLLABUS ENTRY/EXIT LEVELS

	Entry Level Characteristics	Training Purpose/Exit Level Goal
1.	Knowledge and familiarity with LSO operating environment (Phase I graduate)	Introduction to basic LSO control concepts/demonstrated capability to control aircraft under "sterile" operating conditions
2.	Experience controlling FCLP operations (Phase II "graduate")	Preparation for carrier operations environment (OJT)/demonstrated capability to control aircraft under day and night conditions
3.	Experience controlling day carrier landings (Squadron LSO designation)	Introduction to complex operating conditions/demonstrated capability to control multiple aircraft types in moderately difficult conditions
4.	Experience controlling night carrier landings (significant progress toward Wing LSO designation)	Preparation for Wing LSO designation/ demonstrated capability to control most aircraft types in significantly difficult and complex conditions
5.	Wing LSO designation; proficient but facing period of inactivity from LSO tasks	Proficiency maintenance
6.	Experienced LSO returning from non-LSO tour of duty (Wing LSO designation or higher)	Refresher training

perspective he can expect when assigned to work on a different ship. This would be especially useful for a Readiness or Training Squadron LSO whose pilot training duties take him to many different ships. Another use is the preparation of a Readiness or Training Squadron LSO for the unpredictability of pilots in the initial carrier qualification training environment. The system could also become a vehicle for conducting periodic formal proficiency checks on LSO performance as is currently done for pilots in flight simulators.

An LSO training system has significant potential as a research tool for the investigation of trainee selection and job performance enhancements. Very little has been achieved in the development of objective trainee selection criteria. The system could be capable of providing trainee performance data relevant to the enhancement of trainee selection criteria. With adequate fidelity in certain aspects of the LSO job, data could be provided for the investigation of job performance enhancements and LSO task standardization. As a closed loop system incorporating models of both pilot/aircraft and LSO, the system would have the capability for investigating the effects of manipulating many of the variables of the job environment. This type of data could lead to enhancements in LSO/pilot interaction effectiveness.

Convenient location of the training system to major LSO population centers is an important consideration for successful system implementation and efficient utilization. There are five major population areas for fleet LSOs: Norfolk, Va., Jacksonville, Fla., San Diego, Ca., Lemoore, Ca., and Whidbey Island, Wash. Within these areas are included seven naval air stations with potential system users. The Norfolk and San Diego areas each have over 50 potential users assigned (San Diego has slightly more than Norfolk). The remaining three areas have about 30 potential users each. If only two systems were available, Norfolk and San Diego would be the most desirable locations due to LSO population and the location of the type commander LSOs in these areas. Since this would accommodate only half of the total LSO population, it appears necessary to locate at least one training system in each of the five areas.

The Naval Air Training Command also has a need for LSO skill acquisition and proficiency support. There are three LSO population centers: Corpus Christi, Texas, Meridian, Miss., and Pensacola, Fla. These three areas encompass five naval air stations. There are approximately 20 potential users in the Corpus Christi area, 7 in Meridian and 7 in Pensacola. Also, Pensacola is the location of the LSO Phase I school (with approximately 12 students) and Corpus Christi is where the type commander LSO is located. Corpus Christi and Pensacola are the most logical training command locations for LSO training systems.

IMPLEMENTATION UNCERTAINTIES. There are several uncertainties associated with training system implementation; these exist in two areas: technology and training effectiveness. Simulation technology has progressed rapidly in recent years. There are impressive image generation and display system applications in existence in the field of training. Significant advances are being made in the application of auto-adaptive training concepts to pilot training systems. Automated speech understanding applications are surfacing in several training system developments. A cursory glance at technology leads one to optimistically view potential technological capabilities, but also tempers that optimism with the reality of system costs. Specific technological uncertainties relevant to an auto-adaptive LSO training system include: visual image generation, visual display, automated voice understanding, automated performance measurement, adaptive control of complex training scenarios, etc. Later portions of this report address these and other issues.

Uncertainties in the field of training concerning how individuals learn specific skills, how to devise optimum training strategies, and how to determine relevant performance measures impact the effective utilization of sophisticated training systems. Cost is also a major factor in the resolution of training uncertainties because of the frequent shortage of empirical data to support training effectiveness predictions. Specific training effectiveness uncertainties relevant to an auto-adaptive LSO training system include: relevancy of LSO environmental cues, modelling of LSO behavior, modelling of LSO learning process, strategies for promoting LSO learning, training transfer from simulated environment, relevant performance measures, etc. In terms of the adaptive training concepts described earlier these and other factors impact each of the adaptive training elements. Instructional alternatives are affected by questions concerning cue relevancy. Performance measurement is affected by questions concerning the adequacy of LSO responses as measures of cognitive processes. Adaptive logic is affected by questions concerning applicability of learning models to optimal syllabus control.

None of the uncertainties described above appear beyond resolution. Some direction for empirical resolution has resulted from this study. Efforts of other organizations are focused on many of the problems. The successful development of a cost-effective LSO training system must include the continual reassessment of these uncertainties in order to advance toward the resolution of the most critical issues.

SUMMARY

This section of the report has shown the applicability of auto-adaptive training concepts to LSO training. Functional concepts and a preliminary syllabus of instructional alternatives for system implementation have been described. Additionally, a context for system and syllabus implementation has been presented and implementation uncertainties identified. These provide a framework for the specification of system functions and performance capabilities presented in the next section of this report.

SECTION V

LSO TRAINING SYSTEM

INTRODUCTION

This section presents the rationale for, and description of, an auto-adaptive LSO training system. The system functional architecture is based on the training requirements, auto-adaptive training concepts, syllabus and implementation context described earlier. The functions are described in performance capability terms and correlated to state-of-the-art technological capabilities. System alternatives are also addressed.

APPROACH

The objective of this portion of the study was to specify auto-adaptive LSO training system performance capabilities. There were two major aspects to the definition of an auto-adaptive LSO training system: determination of candidate system functions and assessment of technological capabilities to support the functions. In achieving the objective there was significant information interchange between the two efforts to enhance the focus on issues most critical to system design.

The first step was the development of an outline of candidate system functions based on the functional requirements implied by earlier analyses (training requirements). This was essentially a top-down hierarchical development process. Given a preliminary set of functions, a literature review was started to identify key technological issues associated with implementation of those functions. These two preliminary steps established the direction of subsequent efforts, involving concurrent activities in both the functional definition and technology assessment aspects of meeting project goals. Refinement and expansion of a system functional architecture involved analysis of specific job performance and training requirements data elements such as the task listing, questionnaire results, behavioral objectives, and syllabus. For the assessment of technology, the literature review was continued and personal contacts were established to expand collection of data. Technical discussions with government and industry contacts were conducted and candidate systems and techniques were directly observed and evaluated whenever possible. Continual technical interchange among project participants from both the functional and technical aspects of this effort enabled efficient clarification of specific functions. Frequent discussions with LSOs provided additional insight on functional needs. Early identification of technological risks was a goal during this effort. Achievement of this goal enabled meaningful interchange with research oriented personnel concerning system feasibility and the direction of risk resolution for subsequent program activities.

TRAINING SYSTEM FUNCTIONAL ARCHITECTURE

A conceptual basis for the functional architecture was found in the three elements of adaptive training: instructional alternatives, adaptive logic, and performance evaluation. The instructional alternatives element guided the definition of instructional stimuli for the system. The adaptive logic element guided the definition of the instructional control functions of the system. The performance evaluation element guided the identification of trainee evaluation functions. The following paragraphs describe the functional aspects of these three areas in more detail.

Based on adaptive training concepts, the top level of the functional architecture is comprised of three elements: instructional presentation, adaptive control, and performance evaluation. Elements at this level are then broken into twelve second-level elements. The paragraphs which follow describe the second level elements and their relationships to LSO training. Figure 10, at the end of this section, depicts the top three levels of the architecture and can be folded out for reference while reading this and other subsections concerning the training system. The diagram depicts a systematic breakdown of elements; it does not imply information flow or functional equivalence across levels.

The instructional presentation aspect of the system involves the presentation of cues which enable trainee task performance and promote learning. The seven functional elements of instructional presentation are described below:

a. Visual Environment. This involves the presentation and variability of visual cues (other than those associated with LSO workstation displays). Some of the primary visual aspects of the system are the aircraft being controlled by the trainee, the environmental conditions, the carrier deck and instructional effects. A significant portion of the conditions defined for the LSO behavioral objectives and the syllabus are reflected in this system functional element. Additionally, the functional need for artificial effects to enhance trainee perception or to provide instructional feedback is reflected here.

b. Pilot/Aircraft. This involves the representation of aircraft performance from a system control standpoint. The required variability of aircraft performance characteristics, pilot control characteristics, and environmental effects is reflected here. This functional element provides an instructionally controlled, interactive environment for task performance demonstration and practice. There is an obvious requirement for interaction between this functional element and the visual presentation of the aircraft.

c. Audio Cues. This involves the presentation and variability of audio cues which influence task performance. It also reflects the potential use of audio cues for instructional feedback. Radio communications, aircraft engine sounds, and task intercommunications are among the cues identified here.

d. Workstation Displays. Included in this functional element are the representation and variability aspects of LSO workstation displays. The PLAT, WOD indicator and SPN-42 radar indicators are examples of items drawn from the training requirements for incorporation in the system.

e. Workstation Controls. This functional element addresses the availability and operability of items required for trainee interaction with the training environment. The "pickle," the MOVLAS control, and the radio are devices included here.

f. Deck Motion Cues. Functional aspects of this element include representation and variability of carrier deck motion and the effects of a ship turn.

g. Instructional Feedback. This includes the identification of types of feedback which must be controlled. The types of feedback indicated here include information concerning performance evaluation and other information or depictions which assist and enhance the learning process. This element is directed by adaptive logic and implemented by visual and auditory system elements.

Adaptive control involves the selection and control of instructional conditions and situations tailored to the instructional needs of the trainee. Both automated and manual functions are addressed for this element:

a. Selection of Learning Alternatives. This element establishes a functional context for the development of decision logic needed for enhancement of skill acquisition (learning). The functions of (next) task selection and instructional strategy selection are included.

b. Selection of Proficiency Alternatives. This element establishes a functional context for the development of decision logic needed for enhancement of proficiency training. The functions of (next) task selection and instructional strategy selection are included.

c. Instructor Intervention. This element essentially addresses the functional needs of an instructor to operate the system in a manually adaptive mode. The two aspects of this element are display and control.

The final functional aspect of the system is performance evaluation. The need for, and utilization of, objective trainee performance measures guides the definition of these functions:

a. Performance Measurement. This function addresses the extraction of performance data relevant to the three types of trainee skill acquisition: perceptual, decision-making, and response.

b. Scoring. This functional aspect addresses the analysis of trainee performance measurement data. Functions identified include the prediction of performance and comparison of performance measures to that prediction. Outputs from this element support the decision logic in the adaptive control elements.

TRAINING SYSTEM PERFORMANCE CAPABILITIES. The preceding discussion of the system's functional architecture establishes a functional context for detailed descriptions of candidate system performance capabilities. The capabilities are in fact "candidates" since future empirical verification is required. This portion of the report is organized into twelve parts, corresponding to the second-level elements of the functional architecture. Reference to the fold-out, Figure 10, is suggested as an organization aid in the review of subsequent paragraphs.

Visual Environment.

a. Approaching Aircraft (under LSO control):

(1) aircraft types: fleet aircraft types include A-3, A-6, A-7, E-2, EA-6, F-4, F-14, F-18, RA-5, RF-8, S-3 (A-3, RA-5, RF-8, doubtful due to system implementation time frame); training command aircraft include TA-4 and T-2.

(2) position lights: red, green and white lights located on different parts of the aircraft; positioning of the lights varies by aircraft type; intensity and operability of individual lights under instructional control of the system.

(3) AOA lights: red, amber and green lights located on front portion of aircraft (usually the nose wheel strut area); intensity of the lights and operability of individual lights under instructional control of the system; lights correlated to aircraft speed.

(4) aircraft dynamics: pitch, roll, yaw angles; speed.

(5) aircraft configuration variations: positioning of landing gear, flaps, speedbrakes, tailhook, wingsweep (F-14 only).

(6) engine smoke: only some aircraft; intensity and frequency of visibility correlated to pilot control actions.

(7) flight control surfaces: horizontal stabilizer (tail); questionable value.

(8) DLC light: S-3 only; blue.

b. Operating Environment:

(1) ambient light: day, night, dusk conditions; color capability for day scene is of questionable value.

(2) weather-effects: reduced visibility, ceiling, cloud formations.

(3) horizon-definiton: continuum from well-defined to non-existent.

(4) plane guard destroyer: ship positioned approximately one mile behind carrier; red mast lights.

(5) carrier wake: sea disturbance trailing carrier; variable intensity correlated to ship's speed.

(6) heavenly bodies: sun, moon, stars; variable positioning.

(7) ocean texture: variable from glassy appearance to rough water (white caps); questionable value.

c. Aircraft Carrier. There are several relevant characteristics of the aircraft carrier structure and equipment. It is very questionable whether all aircraft carrier configurations must be simulated. Alternatives include the simulation of a generic carrier and the specification of groupings of carriers with similar characteristics. Relevant characteristics are described below:

(1) deck outline: deck edge in LSO field of view, aft end of deck ("ramp"); two general deck edge outlines (straight edge aft of LSO and notched deck edge); there are three carrier groupings with similar outlines; deck edge variability of questionable value.

(2) deck lighting: red deck edge lights, white landing area outline lights, white floodlight effect in landing area; all but deck edge lights of questionable value.

(3) deck markings: landing area and ramp markings.

(4) clear/foul deck lights: red and green lights in LSO field of view; variable intensity and operability.

(5) island: superstructure on starboard side of ship; various red and white lights; of questionable value.

(6) arresting wires (cables): four cables in landing area; only in LSO field of view during latter portion of approach and touchdown.

(7) LSO platform positioning: two aspects, position relative to deck shape (offset from centerline, distance from optimum aircraft touchdown position and distance from ramp) and vertical position of platform (flush vs recessed); dependent on specific carrier, though there are three carrier groupings with similar dimensions.

d. Pattern Aircraft. Simulation of other aircraft in the landing pattern is of questionable value. However, there are two potentially relevant characteristics:

(1) Lighting: position and AOA lights (as described earlier).

(2) dynamic positioning.

e. Instructional Effects.

(1) alphanumerics: for data presentation and for graphics annotation.

(2) graphic depiction: for artificial and exaggerated cues; straight and curved lines, surfaces; highlighting.

Pilot/Aircraft.

a. Aircraft Performance Characteristics.

(1) aircraft types: as indicated in Visual Environment.

(2) flight characteristics: pitch, roll, yaw, speed.

(3) performance capabilities: vertical, lateral, acceleration/deceleration and waveoff responsiveness; capabilities correlated to configuration and system malfunctions.

(4) configurations: positioning of landing gear, flaps, speedbrakes, wingsweep (F-14 only).

(5) malfunctions: engine failure, hydraulic failures, flight control malfunctions, landing gear malfunctions, APCS malfunctions, ACLS malfunctions.

b. Pilot Characteristics

(1) overall skill level: continuum of skill levels from low to "ideal" (perfect pilot) in terms of both under-control and over-control; unskilled but with some degree of predictability; unpredictable.

(2) skill level in specific control aspects: individual variability (as described above) in glideslope, lineup, speed control.

(3) control responsiveness to LSO: continuum from no response to over-reaction, including incorrect responses.

(4) configuration responsiveness to LSO: control of landing gear, flaps, speedbrakes, wingsweep, tailhook.

c. Environmental Effects.

(1) wind: speed, direction.

(2) "burble" effect: airflow disturbance just aft of the carrier.

Audio Cues.

a. Radio Communications. communications are received by LSO through hand-held device and LSO console loudspeaker. Communications sources are described below and the requirements for interaction with the training scenario are identified:

(1) pilot in approaching aircraft: "meatball" call at commencement of approach (i.e., "104, Phantom ball, five point zero, auto"); interactive.

(2) CATCC: radio calls to the approaching aircraft prior to LSO control and others in the pattern; calls to approaching aircraft interactive, others not interactive.

(3) Air Boss: calls to aircraft in pattern and on deck; not interactive.

(4) pilots in other aircraft: calls to ship concerning approach, tanker location, fuel state, ship heading, etc.; not interactive.

b. Environmental Sounds.

(1) engine sounds of approaching aircraft: variations in pitch and intensity correlated to pilot throttle control; interactive.

(2) noises on deck: aircraft, flight deck vehicles; non-interactive.

(3) environment: wind, ocean; non-interactive.

c. Non-Radio Communications.

(1) intercommunications: speaker on LSO platform for communications from Air Boss, CATCC, Air Ops, Ready Rooms; some calls interactive.

(2) deck PA system: communications from Air Boss, Flight Deck Control, Bridge: some calls directed to LSO; probably non-interactive.

(3) LSO platform voices: backup LSO, hook spotter/phone talker; interactive.

(4) instructional communications: from instructor or system; related to instructional feedback.

Workstation Displays. Most items are incorporated in console adjacent to LSO platform:

a. PLAT. Televised view of approach from deck centerline; cross hairs for optimum aircraft position.

b. WOD Indicator. Wind speed, direction relative to ship heading.

c. Hook-to-Ramp Indicator. Dynamically shows relative positioning of ramp to optimum glideslope.

d. FLOLS Indicators. Basic angle, roll angle, and brightness settings; brightness setting of questionable value.

e. SPN-42 Radar Indicators. Speed (true or closure), line-up deviations, glideslope deviations, ACLS Mode, Waveoff.

f. SPN-44 Radar Indicator. Speed (true or closure).

g. Waveoff Indicator. Red light near LSO console indicative of waveoff light activation.

h. MOVLAS Position Indicator. On some ships; indicative of MOVLAS signal positioning.

i. HUD. Emerging system; LSO job aid providing improved presentation of aircraft and landing aid information; questionable due to implementation uncertainty.

j. CLASS. Emerging system; improved landing aid information; questionable due to doubtful future implementation.

Workstation Controls.

a. "Pickle". Hand-held device for activating waveoff and cut lights.

b. MOVLAS Control. Hand-operated lever for signalling perceived (LSO) glideslope position of aircraft.

c. Radio. Hand-held voice transmit-receive device for radio communications.

d. Intercom. Console-located switches for intercommunications to Air Boss, CATCC, Air Ops, Ready Rooms; of questionable value.

Deck Motion Cues.

a. Roll. Dynamic rotation and static positioning (trim) about longitudinal axis of ship.

b. Pitch. Dynamic rotation and static positioning (trim) about lateral axis of ship.

c. Heave. Dynamic vertical displacement of the ship.

d. Yaw. Dynamic rotation about the vertical axis of the ship.

e. Ship turns. Change of ship heading and resultant pitch, roll, yaw and heave dynamics.

Instructional Feedback. This addresses the controllability of different types of feedback. Presentation functions are addressed under Visual Environment and Auditory Cues covered earlier.

a. Evaluative Feedback. Scoring, diagnosis and specific performance information; performance replay.

b. Exercise Information. Information concerning exercise descriptions, conditions, purposes, etc.

c. Transfer. Information correlating exercise tasks to prior skills.

d. Demonstration. Presentations of ideal performance, typical performance errors, etc.

Selection of Learning Alternatives.

a. Task Selection. Selection of the next skill to be learned or practiced.

b. Instructional Strategy Selection. Selection of the optimum exercises and/or instructional effects which promote learning of the skill selected above.

Selection of Proficiency Alternatives.

a. Task Selection. Selection of the next skill to be practiced.

b. Instructional Strategy Selection. Selection of the optimum exercises for skill maintenance.

Instructor Intervention. Functions enabling the instructor to act as an adaptive training controller. Strong potential requirement for collocation of instructor and trainee.

a. Display. Information concerning instructional strategy, exercise conditions, trainee performance evaluation.

b. Control. Manual control of information accessibility, exercise conditions (visual, pilot/aircraft, audio, trainee workstation displays/controls, deck motion, instructional effects as described in earlier sections).

Performance Measurement. Functional support for evaluation of perceptual, 1 decision-making and response skills is needed. There are two direct behavioral measurements:

a. Voice Calls. Extraction of data relevant to LSO radio voice calls.

b. Control Activations. Extraction of data relevant to LSO control activations (MOVLAS, waveoff lights, cut lights, radio).

Scoring.

a. Performance Predictions. Specification of predicted LSO performance relative to exercise conditions.

b. Performance Comparison. Comparison of performance measurement data to predicted performance.

TECHNOLOGY ASSESSMENT

This subsection presents information concerning the state of training technology relevant to an auto-adaptive LSO training system. The information describes the technological design considerations associated with each of the 12 second-level elements in the system functional architecture. Information concerning specific technical applications or techniques which appear relevant and feasible are described and design limitations are identified. A significant portion of the effort involved in this study was focused on visual simulation technology because of its critical role in the envisioned system design and implementation context. A general overview of visual simulation technology is presented in Appendix H. The most pertinent visual system assessments and conclusions are summarized below.

VISUAL ENVIRONMENT. From a technological standpoint, there are two functions of concern to the LSO training system visual simulation: (1) image generation, and (2) image display. This functional separation is not always evident when reviewing technical literature or discussing specific applications. Recognition of this separation is important to the objective review of visual simulation. Effective evaluation of candidate systems and techniques is also dependent on identification of relevant design considerations which are implied by the candidate performance capability requirements described earlier. In the case of visual simulation, an understanding of the types of human visual acuity (i.e., separable acuity, the ability to resolve two objects); and perceptible acuity (the ability to discriminate or detect one object in another) was found to be a useful departure point for technical assessment. Technological design considerations are derived from the candidate functional performance capabilities described earlier and are described below. These are potential parametric constraints and must be empirically resolved prior to system definition:

a. Field Of View (FOV). Possibly up to 180° (horizontally) by 60° (vertically).

b. Resolution. Aircraft with 40 foot wing span (F-14, A-7) at 1.5 miles has about 17 arc minutes of wing tip separations, visible wing/flap thickness of about 5 feet covers about 2 arc minutes, separation of point lights on aircraft is approximately 8 arc minutes at 1.5 miles.

c. Color. Point light colors of red, green, amber, white, and perhaps blue; surface color requirement questionable.

d. Simulated Ambient Light Conditions. Day, dusk, night continuum. Night is required; day and dusk are questionable.

e. Luminance. Potential requirement of 10 foot lamberts for day scene; interrelated to resolution — as luminance decreases, ability for human to perceive resolution decreases. Reflected light from night scene surfaces could be considerably less than for day.

f. Contrast. Interrelated to resolution — as contrast ratio decreases, ability of human to perceive resolution decreases. Contrast requirement for night scenes is well within state-of-the-art.

g. Viewing volume. Potential requirement for two viewers of same display, approximately 2-3 feet head-to-head.

h. Simulated Scene Elements. Lights, lines (including curved lines), shapes, surfaces; possible aircraft control surface movements.

Several of the more relevant visual simulation applications are described below in terms of advantages and limitations. For organizational purposes they are divided into image generation and image display:

a. Image Generation. Of the candidate image generation techniques, a camera model system and Computer Generation of Imagery (CGI) are considered most relevant to the LSO training system. The Model technique provides realistic, detailed, visual information. Its potential drawbacks are:

(1) Ability to provide a night scene is questionable

(2) Mechanical lags, tolerance, backlash and overshoot problems

(3) Resolution is only fair

(4) Scene cannot be changed in real time without additional hardware

(5) No provision for artificial instructional effects

CGI provides many positive features with a few drawbacks. Adaptive training is facilitated by image controllability and flexibility inherent in CGI performance. Instructional effects are available. Scene detail and elements are variable in real time. Scene detail can be very high for a specific scene element (such as the aircraft). Night, dusk, and day scenes, and variable weather conditions are available. The major drawback of CGI is limited scene complexity (only 8,000 edges currently available). However, this limitation is likely to decrease in the near future (two years or less) and today's 8,000 edge capabilities appear to be adequate for an LSO application.

b. Image Display. Of the candidate display system applications, three are considered relevant to the LSO training system: direct view infinity optics, projection, and a hybrid technique. A direct view infinity optics display system uses a Cathode Ray Tube (CRT) coupled with an optics system causing the CRT image to appear at infinity. These systems are compact, relatively reliable, and of medium cost. Their viewer volume is nominally restricted to 6 inches precluding multi-viewer use (a potential LSO training system requirement) and potentially hindering LSO equipment positioning. Two CRT types are used in direct view infinity optics display systems, Beam Penetration CRT (Calligraphic) and Raster Scan CRT. Beam Penetration systems offer high resolution but cannot generate blue lights (however there are recent developments which may remove this limitation). They work well in night and dusk applications. Raster Scan offers full color capabilities as well as relatively high brightness and contrast in day scenes but is significantly more complex and costly than calligraphics. FOV per channel (for both CRT types) is usually 48° x 36° and channels can be combined to provide increased FOV. Raster Scan CRTs typically have half the resolution of the calligraphic CRTs.

Two projected view image display systems are of interest (Raster Scan Video and Laser). Raster Scan video offers two projection techniques of interest. Both techniques provide a large viewer volume and unhindered space for LSO equipment. One technique combines 2 or more individual channels and flat screens to provide desired FOV. The second technique combines a very wide FOV (low resolution background projection), with a very narrow FOV (high resolution target projection) on a hemispherical screen. The first projection technique using multiple channels would provide a good background scene but may lack adequate resolution for the approaching aircraft. The second projection technique provides both the FOV necessary for the background scene and potentially high resolution for the aircraft. It is, however, somewhat low in contrast and luminance. Laser projection systems are still in a developmental stage. Production may be possible within two years. Laser systems provide excellent FOV and have the potential for high resolution without requiring a separate target projector. Projection is usually comparatively expensive, requires larger facilities, is more complex and may be less reliable than a comparable TV system.

There is a hybrid display system which is a combination of infinity optics and projection technology. It provides large viewer volume and unhindered space for LSO equipment. Unfortunately, it apparently combines the disadvantages of both techniques resulting in questionable resolution, low contrast and luminance. These problems may be solvable by incorporating a target projector technique and higher intensity projectors.

PILOT/AIRCRAFT. Design considerations relating to pilot/aircraft simulation functions include the variability and controllability of two types of performance characteristics: pilot and aircraft. Implementation of pilot characteristics must account for variable control responsiveness to basic carrier landing influences (control of glideslope, lineup and speed dimensions) and responsiveness to LSO signals. Implementation of aircraft characteristics must account for variability of aircraft performance by aircraft type and responsiveness of this performance by pilot and environmental influences.

These considerations appear best implemented with a single model of pilot performance and separate models of aircraft performance for each aircraft type. Adequate aircraft performance models appear to be available in the field of training technology. The existence of a pilot model, of adequate complexity to meet system performance capability needs, appears questionable.

AUDIO CUES. There are two design considerations for the audio cue functions. The first involves whether interaction with the training exercise is required. The second involves the distinction between verbal and non-verbal audio. Audio tape storage and generation appears adequate for all non-interactive cues (both verbal and non-verbal). Interactive, verbal audio can be implemented by three techniques of voice generation: synthesized, digitized, and analog. Synthesized voice generation constructs words from fixed phonetic components. Digitized voice generation digitally breaks down, stores and reconstructs spoken words. Analog voice generation accesses pre-recorded words from a random-access drum in real time. Of these alternatives, synthesized voice generation is the most flexible and has fewer restrictions on vocabulary size. Digitized and analog voice generation techniques are restricted to pre-programmed or recorded vocabulary. Implementation of interactive, non-verbal audio (aircraft engine sound; pitch and amplitude characteristics) is less certain. Special purposes hardware is required for implementation of this function.

WORKSTATION DISPLAYS. The fidelity (realism) requirements of LSO workstations displays have yet to be established. Fidelity is a consideration from three aspects: appearance, location, and operation. It is estimated that adequate fidelity can be maintained by either stimulation or simulation for all displays. Stimulation is suited to instruments requiring analog, digital, or synchro inputs. This includes all workstation displays except the PLAT and HUD.

Simulation appears to be the least complex and least costly method of implementing PLAT and HUD. The PLAT could be a stand-alone visual system utilizing graphic CRT system. Replication of the "see through" aspect of the HUD does not appear necessary since it is seldom used in that context. Therefore a simulation of the HUD and its accompanying instrumentation could be simulated on a second CRT as a part of a combined PLAT/HUD visual system.

WORKSTATION CONTROLS. The workstation controls should serve as realistic job performance devices for trainee interaction with the training system. For this reason actual equipment implementation is desired. The actual "pickle", incorporating two discrete on/off switches, is easily implemented. The actual MOVLAS control, a digital hand control, is also easily implemented. The hand-held radio transmit device (which resembles a standard telephone receiver) should be similar to actual equipment and is easily implemented in the training system's communications system.

DECK MOTION CUES. Accurate perception of deck motion influences on the exercise environment is the prime consideration here. The alternative implementations include incorporation of the motion only in visual simulation or development of a multi-axis LSO platform motion system working in conjunction with motion in the visual simulation. Implementation with only visual simulation is the most practical design, and appears to be adequate. However, without physical motion there is a remote possibility that the disparity in cues could cause discomfort to the viewer.

INSTRUCTIONAL FEEDBACK. The implementation of instructional feedback as described earlier rests upon the development of the appropriate data bases for each of the four types of instructional feedback.

a. Evaluative Feedback. This form of feedback is completely dependent on the definition of an adequate model of student LSO behavior. Replay techniques are well within the current state-of-the-art.

b. Exercise Information Feedback. This will require the development of a data base so that student performance on particular tasks can be correlated with specific learning difficulties.

c. Transfer Feedback. Again a data base must be established before this form of feedback could be confidently implemented.

d. Demonstration Feedback. Like evaluative feedback, demonstration feedback is dependent upon the adequate definition of a model of student LSO behavior. Typical student error types of feedback will have to await the development of an adequate data base.

SELECTION OF LEARNING ALTERNATIVES. The technological risks or uncertainties of this topic revolve around the specification of the optimization model for the task selection and the learning model for instructional strategy selection. There are many candidate models for each process. However, the major complicating or limiting factor is the availability of a data base for empirical evaluation of the models.

SELECTION OF PROFICIENCY ALTERNATIVES. The technological risks or uncertainties of this topic revolve around the specification of the optimization model for task selection and the proficiency model for instructional strategy selection. There are many candidate models for each process, however, the major complicating or limiting factor is the definition of a data base for empirical evaluation of the models.

INSTRUCTOR INTERVENTION. The design considerations involved with instructor intervention functions are concerned with the accessibility of information and control of the training exercise. Complicating these considerations is the potential desirability for varied levels of automation of instructional control, (i.e., from manual to total automated). Another complication is the desired co-location of instructor and trainee.

Design of two instructor stations appears desirable for the satisfaction of instructor invention functions. An "on-board" station could be equipped with a hand-held display and control device. This would enable control of the exercise and accessibility to critical information (primarily performance evaluation data). An off-line station would provide extensive control of the exercise and accessibility of information. A single display oriented to the approaching aircraft with cues for perceiving position and speed deviations should be adequate representation of the trainee's visual scene. A second display could support additional information requirements, probably through menu-selection accessibility techniques. Exercise and information control via direct interaction with the second display is a feasible design concept.

PERFORMANCE MEASUREMENT. Performance measurement must support evaluation of perceptual, decision-making, and response skills. Performance measurement implies the extraction of data required for performance evaluation. Although all data requirements are not yet determined, voice calls and LSO, control activations (as measurable overt responses) are measures relevant to LSO performance. "Pickle" and radio transmit actions are discrete on/off states implementable through digital interface. MOVLAS control actions are multiple state changes and easily implementable through digital interface. A speech understanding system (SUS) is feasible for extraction of LSO voice call data. The current state-of-the-art in SUS is Isolated Word Recognition

(IWR) which appears adequate for the LSO training system application. The ability of SUS to adequately distinguish between variations in amplitude (such as "power," "POWER!") appears feasible, but must be evaluated. Effective application of SUS will be dependent on consistency of recognition. This will be influenced by the adequacy of the Voice Data Collection (VDC) 0 technique employed to train SUS to the trainee's voice patterns.

SCORING. Scoring routines will be defined by the learning models that are adopted to control the selection of instructional alternatives. The technology required for implementing these routines, once they are defined, is well within the capabilities of current hardware and software techniques.

TRAINING SYSTEM DESIGN ALTERNATIVES

Development of the LSO training system which has been described previously is an ambitious undertaking. The training system is worthy of consideration because of its potential benefits to LSO training effectiveness. Uncertainties which influence the need to identify system alternatives include costs, training effectiveness, and development time. The system design alternatives described below essentially identify contingencies in terms of capabilities other than those identified earlier. The primary inference is that for a reduction in capability there is also a reduction in cost. The determination of where to halt the reduction thus becomes a costeffectiveness tradeoff. The absence of objective methodologies for determining training effectiveness makes this tradeoff very difficult. The purpose of this section is to establish a practical context for future evaluation of cost-effectiveness tradeoff techniques.

There is a continuum of system design alternatives: from a simple, unsophisticated LSO task and environmental demonstration system, to a highly sophisticated auto-adaptive LSO training system which provides an optimum LSO learning environment. The following paragraphs describe four additional alternatives within this continuum in terms of training purposes, capability reductions and estimated training sacrifices. The alternatives to the system described earlier in this report are presented in descending order (subjectively estimated) of system sophistication.

Alternative I would be an auto-adaptive training system less sophisticated than optimum. The purpose of this system would be to support only LSO skill acquisition, not proficiency maintenance for a highly skilled LSO. The visual system would provide fewer cues and less realism than the optimum system. LSO interaction and sophisticated auto-adaptive control would be incorporated. Reductions in capability would exist in visual and auditory systems (fewer cues, less realism, reduced data bases), in adaptive control and performance measurement (no provision for proficiency training logic), and training station equipment (possibly less displays and reduced workstation realism). Sacrifices in skill level achievement, training transfer, and proficiency training would be expected.

Alternative II would be essentially a simulation of the LSO working environment. The purpose of this system would be to provide a medium for skill learning and practice. The visual system required for this alternative would come very close to replicating the real world and would also enable LSO interaction. Capability reductions from optimum would include absence of automated control of instructional strategies, performance evaluation, and artificial instructional tools. The instructor would have to perform manually the role of an "adaptive controller." Sacrifices in training effectiveness and trainee progress efficiency would be expected. Increased instructor workload would be required.

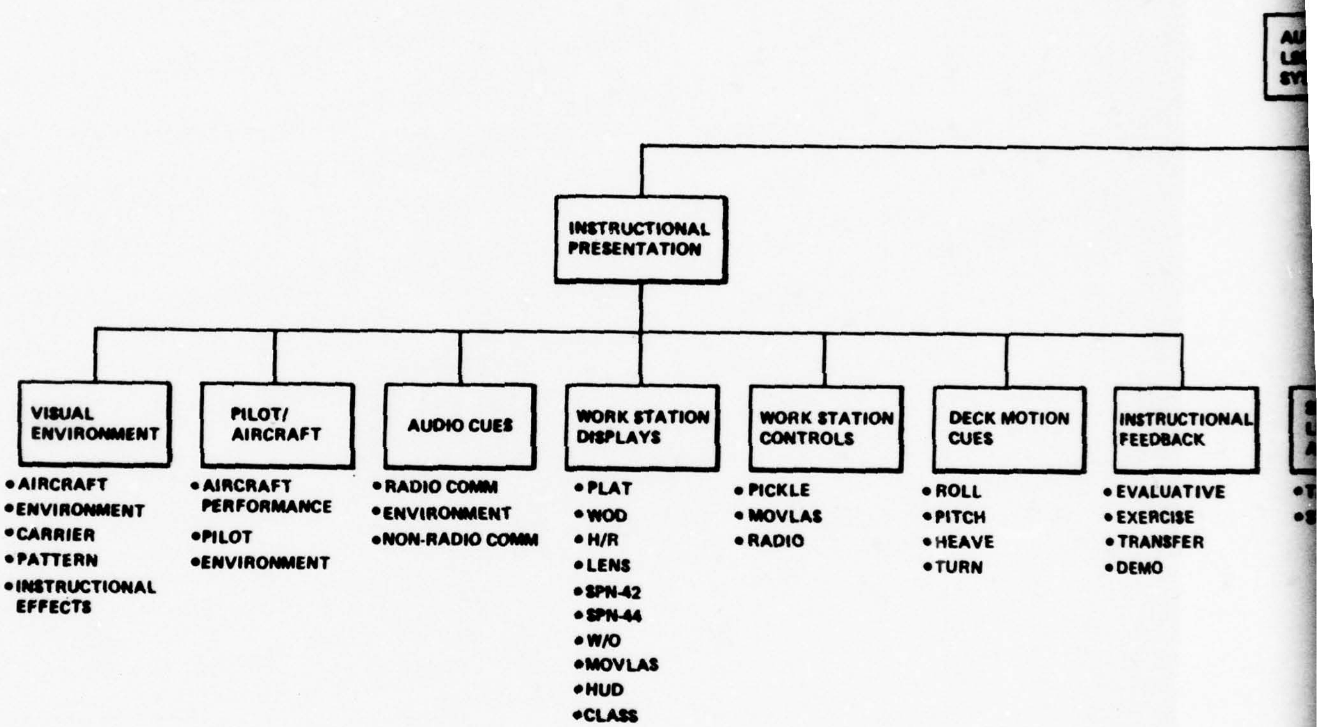
Alternative III would be an auto-adaptive training system significantly less sophisticated than optimum, essentially a part-task trainer. The purpose of this system is to support the acquisition of very basic perceptual, decision-making, and response skills. The visual system would be unsophisticated, involved primarily with the presentation of artificial and exaggerated cues. LSO interaction and sophisticated auto-adaptive control would be incorporated. The primary capability reductions would be in the visual system and in work-station realism. Sacrifices in skill level achievement and training transfer, proficiency training would be expected; sacrifices would be significantly more extensive than in Alternative I.

Alternative IV would be an unsophisticated, non-interactive system. The purpose of this system would be to provide introduction to the LSO operating environment and demonstrations of specific LSO tasks and perceptual elements. Audio-visual subsystems would provide static and dynamic presentations of actual and animated aircraft approaches, LSO task performance, and most of the cues in the operating environment. The capability reductions are extensive (absence of performance measurement, adaptive control, image generation complexities, etc.). Sacrifices include skill level achievement (passive training medium, no performance evaluation) and training transfer.

The system alternatives above were discussed independently. This, however, does not preclude the consideration of a "family" of LSO training systems. The availability of a part task trainer (Alternative III, above) to the LSO training program might relieve some of the training burden from the optimum auto-adaptive training system. This could result in reduced optimum system complexity and reduced utilization (shifting some training time to a lower operating cost system). The "demo" system (Alternative IV) is a promising medium for LSO Phase I training and should be significantly less costly than any of the other alternatives. As progress is made toward the refinement of LSO training system needs the "family" concept should be continually re-evaluated.

SUMMARY

This section has presented the performance capability specification for an auto-adaptive LSO training system. In deriving this specification, a system functional context has been established, technological uncertainties have been identified, and a conceptual context for refining cost-effectiveness tradeoffs has been established. The functional and technical information of this section and the training application information of earlier sections combine to form the basis for the laboratory system design and program activity recommendations that follow.



INSTRUCTIONAL PRESENTATION
VISUAL ENVIRONMENT
•AIRCRAFT
•ENVIRONMENT
•CARRIER
•PATTERN
•INSTRUCTIONAL EFFECTS
PILOT/ AIRCRAFT
•AIRCRAFT PERFORMANCE
•PILOT
•ENVIRONMENT
AUDIO CUES
•RADIO COMM
•ENVIRONMENT
•NON-RADIO COMM
WORK STATION DISPLAYS
•PLAT
•WOD
•H/R
•LENS
•SPN-42
•SPN-44
•W/O
•MOVLAS
•HUD
•CLASS
WORK STATION CONTROLS
•PICKLE
•MOVLAS
•RADIO
DECK MOTION CUES
•ROLL
•PITCH
•HEAVE
•TURN
INSTRUCTIONAL FEEDBACK
•EVALUATIVE
•EXERCISE
•TRANSFER
•DEMO

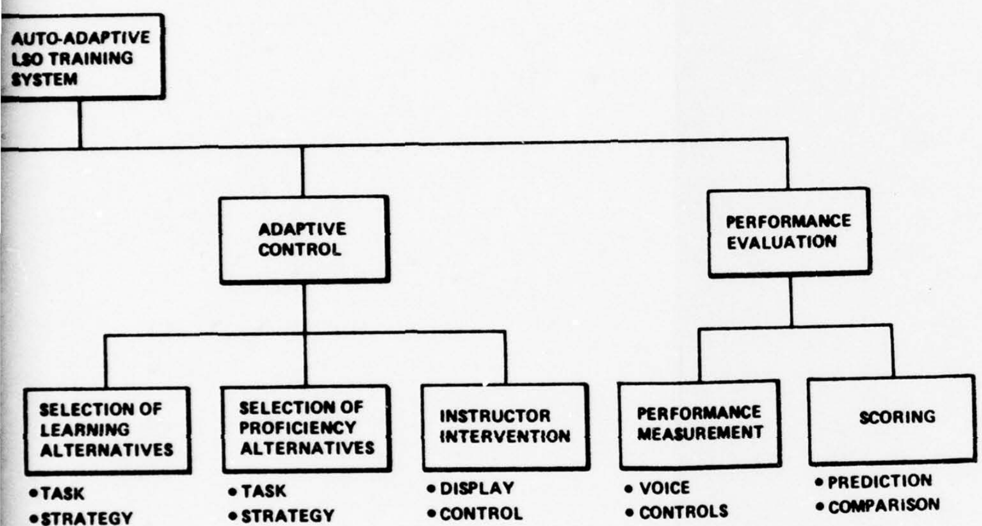


Figure 10. System Functional Architecture

SECTION VI

LABORATORY SYSTEM

INTRODUCTION

Many of the uncertainties associated with the LSO training system concept have been identified by the progression of information (from previous sections) concerned with system design and implementation considerations. Before development of a procurement level specification for the system, significant progress is required in the resolution of these uncertainties. System uncertainties exist in the two areas of training and technology. A tool for continued progress in both areas is an interactive training system for laboratory experimentation.

OBJECTIVES OF THE LABORATORY SYSTEM

Before proceeding to full scale development of an LSO trainer, it is recommended that a simplified laboratory version be developed. At the most fundamental level, the laboratory system will demonstrate to the simulation engineering and LSO user community that a pilotless trainer is feasible and economical. At a higher level, the laboratory system will demonstrate to the same community the feasibility and potential benefit of an automated, adaptive training system. The term, automated, is meant to suggest that only the LSO trainee will be needed to close the loop. The term, adaptive, implies that a well structured syllabus can be implemented and instruction can be automatically tailored to the trainee's need.

In pursuit of the latter objective, much information will be learned empirically about the learning stages and progress rates of a typical person learning the LSO skill. The laboratory system, while having some distinct limitations, will provide valuable information which will suggest the framework of the ultimate training syllabus and syllabus control.

LAB SYSTEM CONCEPT

Very early in the study, it was recognized that a period of demonstration, experimentation, and concept evaluation would be required for a low-cost laboratory version of the automated system. As the study progressed, many questions arose which could not be answered by such a system. These questions centered largely on the requirements of the visual system. In order to answer these questions, recommendations were made for certain lab phase activities (See Section VIII). At the same time, the design of the Interactive Experiments System (IES) was developed and the design outline will be covered in the paragraphs below.

The Interactive Experiments System (IES) will be designed to operate on existing NAVTRAEQUIPCEN lab equipment (depicted in Figure 11), namely the dual NOVA system now in use for speech recognition applications. This

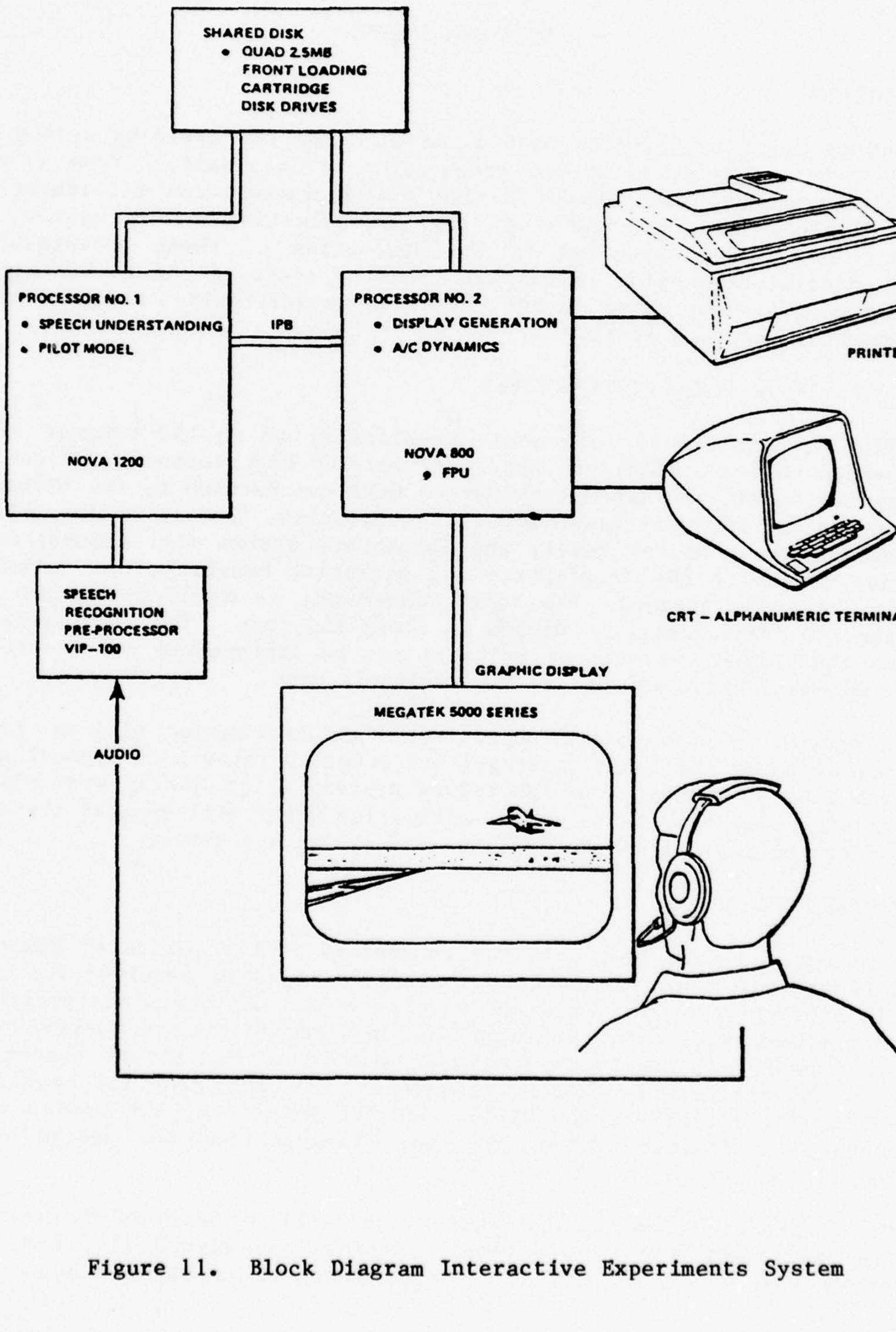


Figure 11. Block Diagram Interactive Experiments System

equipment includes a NOVA 1200 CPU, a NOVA 800 CPU with floating point hardware, a VIP-100 voice recognition preprocessor and interprocessor communication link (IPB), a shared disk featuring two removable and two fixed cartridges, a Megatek series 5000 random scan graphics display, and a Tally model 2200 line printer.

The LSO subject will view the line drawing outline of the approaching aircraft. When he has perceived a need for a corrective action by the pilot, he will make any of the common LSO commands which will be fed to the voice recognition preprocessor. The speech understanding software will compare the signal to stored reference patterns of the allowed phrases and will select the most probable command. Software will process the command to simulate the pilot's response and will compute the aircraft response to the pilot. Thus, the basic closed loop system of vocal control to visual response will be achieved. Advanced experiments will be possible using software additions to this basic framework.

There will be two sets of experiments conducted on the system, (1) basic qualifying experiments and (2) higher level experiments. The basic qualifying experiments will answer questions such as the following:

a. Can the viewer see sufficient attitude and positional changes in the aircraft to adequately control the aircraft?

b. Does the speech understanding system correctly choose the spoken phrase reliably?

c. Does the pilot-aircraft simulation respond in the correct dimensions and degree to LSO commands and "meatball" deviations?

The higher level experiments will be run when the system successfully completes qualifying experiments and will answer questions such as:

a. Does the analytic model of LSO behavior properly categorize LSO commands as to their acceptability?

b. Do various instructional techniques (e.g., graphic perception aids, performance feedback) work in practice?

c. How does change in situational variables affect LSO control quality?

d. What are the typical learning stages and progress rates of an experimental subject? Can the basic skill be taught in such a simplified visual medium?

LAB SYSTEM DESIGN

Figure 12 shows the fundamental processing and data flow necessary to implement the IES. Since existing NAVTRAEQUIPCEN lab equipment provides the necessary hardware environment, the IES development consists solely of software developments.

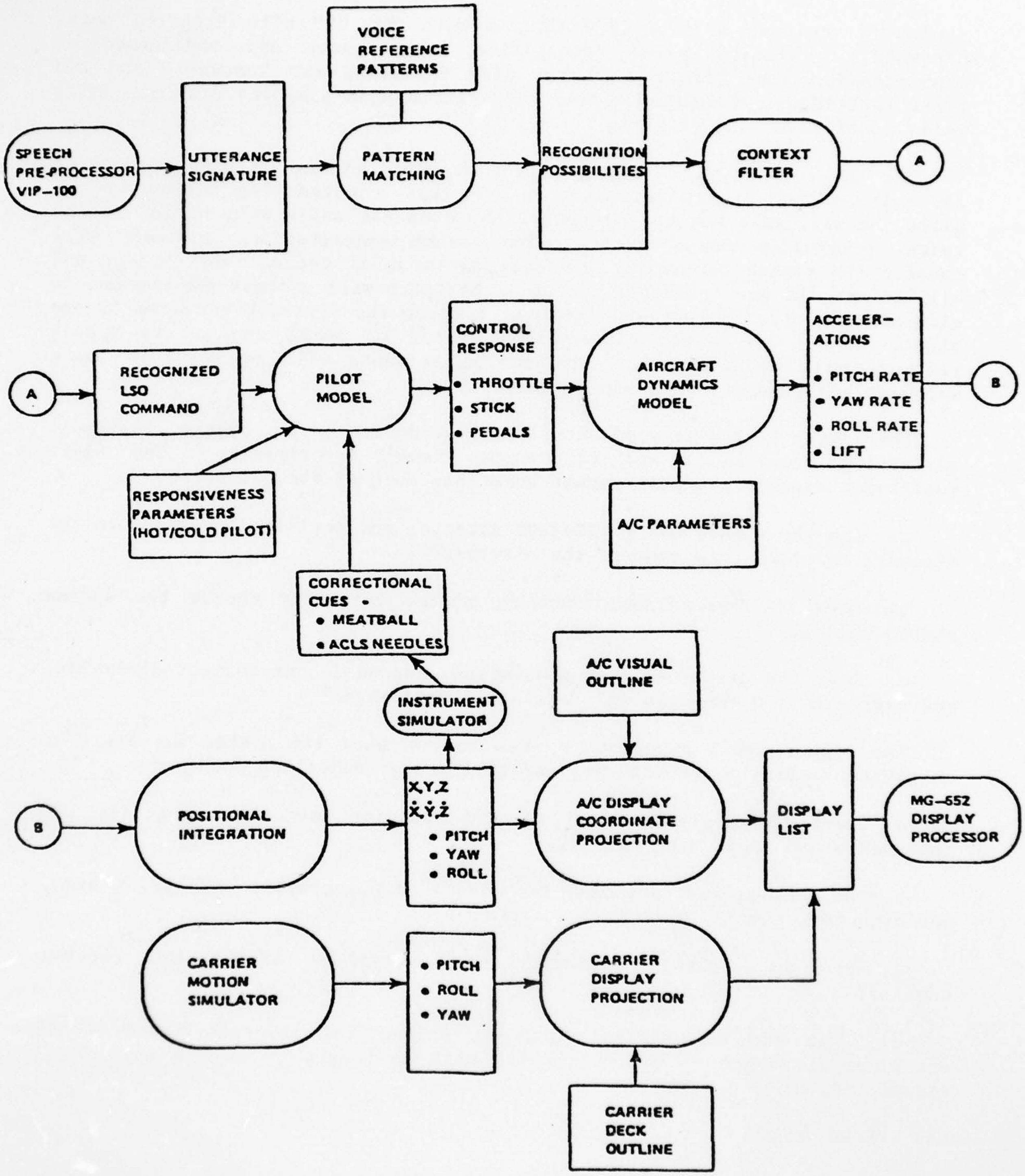


Figure 12. Process Flow Diagram Basic Interactive Experiments System

Specific software development considerations are outlined in the paragraphs below:

a. Visual System (Image Display). The Megatek 5000 series random scan monochromatic 21-inch graphic display will be programmed to portray the dynamic image of an aircraft approaching the carrier deck. The image will encompass a 60 degree field of view from the LSO perspective, and will be centered approximately 25 degrees left of directly aft. This will allow full view of the aircraft from 1.5 miles to a position about 50 feet past the point where the aircraft will pass over the ramp. Deck outline, ship's wake, and horizon will be included. The day aircraft image will be shown in wire model form (i.e., the student will see through the body to the wing outline on the far side with no hidden line algorithm). The night aircraft image will include position and AOA lights without color. The image coordinates will be updated 10 to 20 times per second to affect (apparently) smooth motion. Some graphic aids will be programmed to facilitate recognition of optimum glidepath and deviations. Display software will be tested first to ensure that the viewer will adequately perceive small deviations in position and attitude in this medium. Some exaggeration of cues may prove necessary as a result of this testing. Due to high instruction execution rate needed for the coordinate conversions the majority of this code will be in assembler language.

b. Speech Understanding. A primary goal of the interactive system is the determination of any technical problems existing in computer speech recognition of LSO calls in real time. A vocabulary of approximately 50 phrases is required (see Appendix D). There is no requirement for limited continuous speech recognition (LCSR); isolated word recognition is sufficient. Development work is probably required to distinguish between degrees of imperativeness (i.e., power, Power!). Existing voice data collection (VDC) programs are being used for basic experiments. Later, a tryout of methods of VDC in context tied to tutorial instruction is recommended.

c. Aircraft Model. A software simulation of the aircraft will be incorporated into the LSO system. Testing of speech understanding in real time will not require a realistic aircraft model. Advanced experiments to test performance measurement and LSO modeling will require a realistic model. Logicon will base the computer code for the aircraft model on available FORTRAN code now in use on the PDP-11 system at the NAVTRAEQUIPCEN Human Factors Lab.

d. Pilot Model. A computer code will be developed to simulate the pilot's response to various corrective cues. The primary cues will include LSO calls, meatball deviations, lineup deviations, angle of attack indexer, etc. Advanced experiments will probably require characterizations for different pilot styles and skills such as experienced pilot, unskilled pilot, and tunnel vision (loses lineup control while correcting glideslope deviations). A part of the testing in this area will involve investigation of the implementability of separate pilot and aircraft models as opposed to a combination pilot/aircraft model.

SECTION VII

CONCLUSIONS

This section is intended to provide a synopsis of the major conclusions drawn from the analysis of the LSO training problem and the technological impact of an automated adaptive training system for LSO training. The conclusions are organized so that each major section or subsection is represented with a statement of the general findings of that section. This method of organization should provide the reader with an easy and efficient method of tracing the rationale and/or data that led to a particular conclusion. The numbers in parentheses refer to major sections in the report.

BACKGROUND (II)

a. Given the critical role of the LSO in the carrier operations environment and the high level of skills required in that environment, the requirement for an efficient training program for LSOs is apparent.

b. The objective of this study was to provide a performance capability specification for an auto-adaptive LSO training system.

c. Design traceability and training application accountability were considered critical to the orientation of study results.

LSO TRAINING REQUIREMENTS (III)

APPROACH.

a. In assessing the LSO training requirements, the study relied heavily upon input from the LSO community in the form of discussions, briefings, and responses to questionnaires. The literature was also reviewed to assure a thorough and effective definition of the training requirements.

EXISTING LSO TRAINING.

a. The major problem of existing LSO training is the inefficiency of the program and its direct consequence, the excessive amount of time required to develop a productive LSO.

b. The primary causes of LSO training problems are reductions in carrier operations, inadequate structuring of the training program and reliance upon subjective and mostly undefined performance evaluation procedures.

c. These training problems are reflected in the shortage of productive LSOs and evidence of decreasing LSO skill levels.

d. The most effective solutions to the problem are an objective LSO training system and an improved structure for the overall training program.

THE LSO JOB.

a. The LSO functions in a real-time environment where the complex and dynamic aspects of landing an aircraft on a carrier interact in a (generally) predictable and systematic manner.

b. The most critical task of the LSO is to control aircraft. This involves three basic functions: perceptual skills, decision-making skills, and response skills.

LSO BEHAVIORAL OBJECTIVES.

a. LSO voice calls and control actions are observable and measurable behaviors indicative of trainee skill achievement.

b. The exact conditions under which these behaviors become appropriate have not been specified. However, the specification of these conditions is an empirical question which is answerable.

AUTO-ADAPTIVE LSO TRAINING (IV)

LSO TRAINING SYSTEM CONCEPT.

a. An automated training system with auto-adaptive control characteristics offers a significant potential for improving LSO training.

AUTO-ADAPTIVE TRAINING CONCEPTS

a. The sequencing of the syllabus must be objectively validated and adjusted and the effects of combining situational variables must be empirically determined.

b. An LSO performance model and a student performance model are critical to the effectiveness of performance evaluation.

c. There appear to be three hypothetical stages of LSO training: perceptual, decision-making, and response learning. Performance metrics for each hypothetical activity must be defined.

d. Learning and optimization models must be defined, tested and evaluated for each of the hypothetical learning activities.

IMPLEMENTATION CONSIDERATIONS.

a. Associated with each of the three elements of an adaptive system are technical uncertainties that may impact the implementation of the system.

b. The uncertainty associated with the instructional alternatives resides primarily in the specification of perceptual cue relevancy.

c. The uncertainty associated with performance measurement resides primarily from difficulties in measuring cognitive events.

d. The uncertainty associated with adaptive logic is associated with the practical applicability of learning models and syllabus control optimization theory to LSO training.

e. An auto-adaptive LSO training system could prove to be an excellent tool for investigations of LSO job effectiveness and LSO selection criteria improvements.

THE LSO TRAINING SYSTEM (V)

APPROACH.

a. Frequent interaction among functional definition and technology assessment activities was considered the key to early definition of critical design issues.

TRAINING SYSTEM FUNCTIONAL ARCHITECTURE.

a. The three elements of adaptive training established a firm conceptual basis for the system functional architecture.

PERFORMANCE CAPABILITIES.

a. Candidate performance capabilities are primarily concerned with the controllability and availability of conditions which promote learning.

b. The candidate performance capabilities for the visual environment are extensive but the most critical and complex is the visual depiction of the aircraft under LSO control (level of detail, resolution, light colors, dynamics, multiple aircraft types).

TECHNOLOGY ASSESSMENT.

a. System design considerations approach the state-of-the-art in several technological areas. This resulted in an increase in depth of assessment of such technologies as visual simulation, speech understanding, and auto-adaptive control.

Visual Environment.

a. Computer Generated Imagery (CGI) is the most desirable technique for image generation in the LSO training system due to its flexibility in providing a variety of controllable images and visual effects.

b. The most desirable technique for image display is yet to be determined. However, if projection is chosen, a technique involving separate projection of background and target looks promising.

c. Close attention to on-going developments in laser and light valve video projectors and infinity optics display systems is essential to timely specification of an acceptable image display technique for the LSO training system.

d. The most important considerations for selection of an image display technique include field of view, resolution, luminance, contrast, viewer volume, and cost.

Pilot/Aircraft.

a. The availability of an adequate pilot model for the LSO training system is uncertain at this time.

Audio Cues.

a. Synthesized voice generation is the most promising alternative for providing interactive voice cues for the training system.

Workstation Displays.

a. The PLAT and HUD appear to be the only workstation displays causing significant design difficulty.

Deck Motion Cues.

a. The most practical implementation of deck motion cues is through the visual simulation subsystem.

Adaptive Control.

a. Difficulties in development of optimal adaptive logic for the LSO training system are caused by the questionable applicability of existing learning models and the lack of a firm data base.

Performance Measurement.

a. Automated speech understanding appears to be a feasible and effective LSO performance measurement tool.

b. Resolution (in the laboratory phase) of questions concerning LSO information processing is needed to direct the form of a performance measurement system.

SYSTEM DESIGN ALTERNATIVES.

a. There are several meaningful and potentially cost-effective alternatives to an instructionally optimum auto-adaptive LSO training system.

b. Significant uncertainty concerning knowledge of LSO learning complicates the development of an objective cost-effectiveness trade-off technique.

LABORATORY SYSTEM (VI)

a. An interactive laboratory system is needed to demonstrate auto-adaptive LSO training concept feasibility and to resolve system design and implementation uncertainties.

b. An interactive laboratory system with the capability to demonstrate concept feasibility and conduct meaningful experimentation can be developed with existing NAVTRAEQUIPCEN hardware.

c. Experimentation to obtain empirical data about the learning of LSO decision-making skills is feasible with the laboratory system.

d. Experimentation to optimize speech understanding techniques for the LSO training system is feasible with the laboratory system.

SUMMARY

The major conclusion of this study is that a cost effective, auto-adaptive LSO training system is a feasible concept.

SECTION VIII

RECOMMENDATIONS

INTRODUCTION

While this study concludes that an LSO Training System is within the state-of-the-art of technology and defines the placement of its use within the LSO personnel cycle, it stops far short of providing the necessary information to procure such a system. Many difficult trade-off decisions remain. Much has yet to be learned about the perceptual and decision-making tasks of an LSO. Much has to be learned about the learning states of an LSO candidate. Progress must be made in these areas to ensure that the ultimate training system is effective.

The recommendations fall into three general areas:

a. Lab Phase. A period of research activity to determine trainer specifications in sufficient detail for procurement purposes.

b. Total Training Program Analysis. The training system is not synonymous with the LSO training program; it is just one tool used in the program. The authors recommend that an analysis effort of the total program be undertaken.

c. Prototype Phase. Once unit 1 of the trainer has passed initial engineering tests, a series of qualification tests for training should be undertaken. These tests should include various learning experiments which will influence ultimate training system utilization.

LABORATORY PHASE

The major objective of the lab phase is to empirically refine and validate the functional requirements and performance specifications for an automated adaptive LSO training system. The end product should include a procurement level specification for multiple LSO training systems.

RISK AREAS. The key to efficient development of an LSO training system is progress toward resolution of all major risk areas. Major risk areas must be adequately resolved to achieve this objective. They are presented below:

a. LSO Behavior Model. This is considered the highest risk area because of several factors. The model is the key element in a successful automated training system. Without it the system becomes only a simulator, dependent upon subjective LSO trainee evaluation by the instructor. Development of a workable model, timely to the procurement process, requires a significant amount of data collection, analysis, and processing. The realism of the model (to the LSO community) and its implementability are sufficiently uncertain to warrant a timely (early in the laboratory phase) and extensive developmental effort. In addition, improved definition of aircraft/pilot/LSO interrelationships is needed to aid the development of a viable aircraft/pilot model for the training system.

b. Visual System (Image Display). Logicon's review of visual system technology has enabled identification of image display as the most formidable technical problem in system design. There are three basic techniques under consideration: infinity optics, projection, and a hybrid arrangement of the two. Infinity optics provides the best display contrast and resolution but has some significant limitations in viewing volume and field of view. Projection (e.g., (AWAVS) provides the best field-of-view potential and environmental realism but display resolution and contrast are uncertain. Current efforts by both industry and NAVTRAEQUIPCEN are addressing improveg ments to both techniques. Laser projection, hybrid infinity optics/ projection system and an improved light valve projector are among other candidates requiring investigation. A primary and secondary media for investigation is recommended.

c. 'Pilotless' System. Significant benefits are realized if the hardware and software of the system can fulfill the role of the pilot's response to the LSO. These benefits include:

(1) reduced cost of operation — A qualified pilot need not be present.

(2) reduced complexity — A cockpit and its controls need not be developed.

(3) difficulty control — A human pilot will probably not be able to fly in a manner to present certain specific control situations; the computer can be programmed to do this.

(4) adaption to alternate aircraft types — A trainer requiring a human pilot would be difficult to reconfigure so as to represent an alternate aircraft type. The human pilot would have to be qualified in type if this were possible.

The application of speech understanding technology allows the development of a 'pilotless' system. The primary risk aspects of speech understanding revolve about the speech stylizations of LSOs. The use of varying volumes of calls, such as "power," to elicit different pilot responses needs further investigation from a system implementation aspect. In addition, the size of the LSO vocabulary and the use of multiple voice calls with similar meanings may pose some system implementation difficulties.

d. Visual System (Image Generation). The authors' review of visual system technology points toward Computer Generation of Imagery (CGI) as a viable and available technique for the LSO training system. There is some uncertainty, however, as there are no current applications which present an image scene similar to that viewed by the LSO. To ensure that industry can demonstrate its apparent capabilities to generate a scene with requisite cues, this technology must be investigated from a technological and a user (e.g., LSO) acceptance viewpoint.

e. Cognitive/Learning Analyses of the LSO. The cognitive (mental) skills of the LSO are assumed to rely heavily on three major components: perceptual processes, decision-making processes, and response processes. As we have discussed earlier these assumed processes are just that, assumed processes. What is necessary is an empirical demonstration of each of these processes so that the question of how do we most effectively train these processes can be meaningfully addressed. Following this demonstration each process must be individually considered and, based upon that analysis, instructional questions can be defined and answered empirically. The risks associated with each are in terms of the functions relating resources invested to the degree of resolution of the question we are asking.

ACTIVITIES.

a. Interactive System. The authors recommend that a series of experiments be developed for evaluation by NAVTRAEQUIPCEN (at their lab) of automated training concepts for application to the LSO trainer. The fundamental software will generate a perspective view of the approaching aircraft on a graphic CRT, perform real-time speech recognition of LSO commands, and simulate pilot-aircraft response. The LSO subject will view the line drawing outline of the approaching aircraft. When he has perceived a need for a corrective action by the pilot, he will make any of the common LSO commands which will be fed to the voice recognition preprocessor. The speech understanding software will compare the signal to stored reference patterns of the allowed phrases and select the most probable command. Software will process the command to simulate the pilot's response and will compute the aircraft response to the pilot. Thus, the basic closed-loop system of vocal control to visual response is achieved. Advanced experiments will be possible using software additions to this basic framework.

There will be two sets of experiments to be conducted on the system: basic qualifying experiments and higher level experiments. The basic qualifying experiments will answer the following questions:

(1) Can the viewer see small attitude and positional changes in the aircraft sufficiently to adequately control the aircraft?

(2) Does the speech understanding system correctly choose the spoken phrase reliably?

(3) Does the pilot-aircraft simulation respond in the correct dimensions and degree to LSO commands and the meatball deviations?

(4) Do the processes of perceptual learning, decision-making, and response learning accurately and adequately capture the essence of the acquisition of LSO skills?

The higher level experiments will be run when the system successfully completes the qualifying experiments and will answer the following questions:

(1) Does the analytic model of LSO behavior properly categorize LSO commands as to their acceptability?

(2) Do various instructional techniques (e.g., graphic perception and decision-making aids, performance feedback) work in practice?

(3) How does change in situational variables affect LSO control quality?

(4) Given that the processes of LSO skill acquisition have been demonstrated, what further specifications of stages, levels, etc. are necessary? And, more importantly, what are the best pedagogical techniques for the LSO training system?

b. Visual Systems Investigations. The primary media would be the Aviation Wide-Angle Visual System. AWAVS is the most suitable tool available for achieving these goals. It is a current state-of-the-art visual display with limited CGI capability. The AWAVS original design concept, which has been carried through to implementation, targets it for experimentation in visual technology.

Through a series of experiments, the minimum acceptable daytime edge count for a monochrome CGI aircraft will be established. Experiments should be done with cue usefulness and cue priorities. Night point light cues should be experimentally examined. Another series of experiments will determine the minimum baseline for resolution, in arc minutes, of the LSO Prototype Image Display Subsystem. A monochrome night display with navigation and angle of attack (AOA) lights should also be experimentally examined.

The final configuration of the LSO Prototype Image Display Subsystem may be a projection video system. Complexity and cost of a projection system could be reduced significantly if the target projector were immovable and the background projector took over when the zoom limit of the target projector had been reached. The feasibility of this approach should be evaluated.

A 60 degree x 180 degree field of view has been suggested as necessary for LSO training in order that the trainee may view the full approach including initial entry into the bolter pattern. A more restrictive FOV would be less costly and could cause only minimal transfer of training loss. However immediate feedback of carrier approach result is lost. This alternative should be examined. The secondary media infinity optics system is one which allows multiviewer participation. It is necessary because the emphasis placed on AWAVS could bias the final prototype specification. AWAVS alone does not provide a means for direct comparison between a projection visual system and an infinity optics visual system. Infinity optics has several potential performance and configuration advantages. The infinity optics system evaluation must be performed so that the trade-off decision between projection and infinity optics may be made. A multiviewer capability must be considered due to the expressed desire of LSOs for instruction within the trainee station.

c. LSO Behavioral Model. Near term research for improving the definition of LSO decision-making behavior will be rewarded by future training effectiveness. LSO behavior will be reflected within an automated trainer design as a part of instructional feedback, performance assessment, and remedial training software.

The quality of the behavioral model will impact the quality of several key automated LSO training system elements and thus impact the effectiveness of the system. The primary element influenced by the model is LSO trainee performance assessment. Other training system elements influenced by the model include adaptive syllabus control, instructional feedback, and remediation control.

The content and sequence of the syllabus for the LSO training system are strongly influenced by the behavioral model. This is due to the fact that the syllabus is based on behavioral objectives derived from job behavior. The LSO behavioral modeling effort defines job performance, thus forming the foundation of all subsequent training requirements analysis activities.

LSO job performance appears to be primarily characterized by perceptual and decision-making behavior. Therefore, identifying job performance situation variables and quantifying their influences on job performance are key elements in the behavioral modeling process. Early analyses of the LSO job have revealed the potential for a significant number of variable influences on job performance. This conclusion has caused the increase in importance which is attached to the behavioral modeling effort and influences the need for increased level of effort in this area.

d. Scale Model. An important part of resolving prototype system uncertainties involves the evaluation of system component dimensions, their alternative arrangements, and their impact on facilities space requirements. This can be accomplished very effectively with a scale model. Additionally, a scale model may help Navy users and procurement individuals to obtain a total system perspective of the various elements under investigation in the laboratory phase. Thus, the model would be both an evaluation and a communications tool. Evaluation of several configuration aspects of an LSO training system would be aided by a scale model. One is the variable level LSO platform within the LSO trainee station. Currently, analysis points to the need for simulating both a flush and a recessed LSO platform. Evaluation of the impact of alternatives for implementing this function would be enhanced by the scale model.

Analysis of system requirements points to the need for an instructor position within the trainee station. Positioning of the instructor and his controls and displays is a task which lends itself to a scale model.

Positioning the trainee controls and displays would be evaluated with the model for therein impact on system design features. Locations of the LSO instrument panel, the MOVLAS and the LSO HUD must be compatible with other system features such as the visual system display components.

Possible computational system space requirements appear variable at this stage of technology assessment, primarily due to variations among visual system candidates. The impact of the space requirements could be easily visualized and efficient component placement would be aided by the availability of the scale model.

e. Technical Specification Development. An early draft release of straw-man specifications for the LSO training system prototype identifying trade-off issues is recommended. Trade-off analysis will occupy the bulk of the effort.

The recommended approach to specification development is as follows:

(1) A straw-man specification in the format of NAVTRAEQUIPCEN engineering specifications would be developed.

(2) In the process of developing the straw-man, weakly supported specification items will be encountered. These items, together with an outline of recommended actions, would be assembled into a trade-off analysis plan. The straw-man specification and trade-off analysis plan should be submitted at the end of three months of effort.

(3) The trade-off analysis following the above plan should span the following 4-6 months of effort. An individual position paper would be released as each analysis task is completed.

(4) In parallel with the trade-off analysis, performance test plans (verification plans) should be developed for the ultimate trainer. The test plans would be designed to ensure that all specification items are met. In addition, recommendations would be made on the method for measuring training effectiveness of the trainer.

(5) After about 10 months, the straw-man specification would be updated and the analysis reports would be edited into a preliminary final report. A review meeting of the preliminary final report should be conducted.

TOTAL TRAINING PROGRAM ANALYSIS

Many of the deficiencies in LSO training are caused by inadequate training program structure and implementation guidelines. Existing LSO training is very inefficient and lacks adequate training resources. The LSO training system addressed in this report is a potentially powerful tool for the improvement of LSO training. Within a systematically derived LSO training program structure, it can be even more cost effective. An analysis of overall LSO training requirements is required to improve training program implementation, efficiency, and enhancement of resource utilization.

The recommended approach should involve an analysis of overall LSO training needs, the identification of supporting resources, and the development of implementation guidelines. The specific activities recommended for this analytical approach include:

a. A comprehensive problem analysis involving the collection and analysis of data concerning training deficiencies, program goals, existing resources, student population, etc.

b. A comprehensive analysis of all LSO tasks.

c. Development of meaningful and measurable training goals and learning objectives for effective LSO job preparation.

d. Identification of training media requirements.

e. Development of an overall program structure of training progress levels and syllabus outlines for academic, trainer, and OJT aspects of LSO training.

f. Development of plans for initial implementation of training program enhancements and guidelines for conduct of LSO training.

It is strongly recommended that the LSO training program analysis effort be concluded prior to the initiation of procurement for the prototype training system. This is due to the potential design influences which could result from the training program analysis. The activities described above would blend nicely with laboratory phase activities described earlier.

PROTOTYPE PHASE

One recommendation for the phase following procurement specification development concerns the location of the prototype LSO training system. LSO population, LSO qualification variety, and aircraft community representation appear to be the most relevant criteria. As described earlier, the San Diego area has the largest LSO population and also includes a type commander (CNAP) LSO. San Diego has a good aircraft community mix including E-2, F-4, F-14 and S-3 aircraft, and has a typical mix of LSO qualification levels. For these reasons San Diego (specifically Miramar Naval Air Station) is the recommended location for the prototype LSO training system.

A second recommendation addresses the need to progress in the resolution of LSO cognitive processing uncertainties. Given that the cognitive processes involved in LSO skill acquisition have been satisfactorily demonstrated in the laboratory phase, the analysis and explication of the input/output functions of each subprocess within the general processes are needed. Given a definitive specification of the mechanisms of the subprocess the next function is to tailor the training system to the pertinent information necessary for processing at each stage. For example, the perceptual system involves the input of information from the environment. The structure of that information may change as perceptual learning progresses. An efficient and appropriate way for the training system to facilitate training is to

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provide, in an exaggerated form, only the information necessary for a particular stage of processing. At the level of the decision-making process, the focus must be upon developing the decision-making strategy. Therefore, the extraction of information may not be appropriate to emphasize and this information can be made as apparent as possible. This would allow the student to concentrate on learning the processes involved in decision making. The important point is that progress must be made in the prototype phase to specify unambiguously the information input to each stage of each cognitive process. In addition to the effort described above, the development of learning models to describe each of these stages or subprocesses is extremely important. These models will guide the specification of performance measurement and the adaptive logic that pertains to that particular skill. The cognitive process in general also requires modeling to assure that the progression of the student follows a logical procedure. Also, each of these sequences of instruction must undergo some form of optimization to ensure that the adaptive logic functions efficiently. These modeling and optimization tasks are primarily data collection tasks that will be conducted during the initial years of the system's exposure to students. However, it seems very desirable that the capability for self-modification of the models and optimization scheme be built into the system as a permanent feature.

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APPENDIX A

LSO TASKS

Subsequent pages of this appendix delineate the tasks performed by the LSO in the control of aircraft landings aboard ship. The tasks are listed and numbered hierarchically in three task levels (e.g. 1, 1.1, 1.1.1). Supporting descriptive information is supplied for each task. LSO job aids, personnel interactions and cues relevant to task performance are identified. Judgment of the relevance of this information is based on interface with LSOs through questionnaire responses, group discussions, and individual interviews.

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
1. <u>ASSESS AIRCRAFT APPROACH</u>				
1.1 Assess aircraft approach parameters				
1.1.1 Vertical position WRT optimum glideslope	PLAT, SPN-42		Visual-positional reference to horizon, carrier deck, plane guard destroyer	
1.1.2 Rate of vertical position changes	PLAT, SPN-42		Visual-positional reference to horizon, carrier deck, plane guard destroyer	
1.1.3 Lateral position WRT optimum track	PLAT, SPN-42	B/U LSO	Visual-positional reference to plane guard destroyer, carrier deck, ship's wake. Auditory-CATCC calls on radio	Most difficult approach parameter to perceive, especially when lined up right
1.1.4 Rate of lateral position changes	PLAT, SPN-42	B/U LSO	Visual-positional reference to plane guard destroyer, carrier deck, ship's wake. Auditory-CATCC calls on radio	
1.1.5 Aircraft range from touchdown	SPN-42		Visual-aircraft size. Audio-CATCC calls on radio	

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
1.1.6 Aircraft pitch			Visual-aircraft fuselage attitude, aircraft lights	
1.1.7 Aircraft roll			Visual-aircraft angle of bank, wing lights	
1.1.8 Aircraft yaw			Visual-aircraft heading WRT track. Audio-prop noise (E-2 only)	
1.1.9 Speed	SPN-42 SPN-44		Visual-aircraft attitude, AOA lights	
1.1.10 Power			Visual-engine exhaust smoke (some aircraft) Audio-engine volume and/or pitch (some aircraft)	
1.2 Assess aircraft status				
1.2.1 Type aircraft		Pilot Hook spotter B/U LSO	Visual-aircraft physical characteristics, lighting positioning. Audio-pilot's "meatball" call	
1.2.2 Configuration		Hook spotter B/U LSO	Visual-aircraft landing gear/flaps/hook positions, AOA light status, wingsweep (F-14 only).	
1.2.3 Fuel state		Pilot Air Ops/ CATCC Air Boss	Audio-pilot's "meatball" call, others intercom	

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
1.2.4 Emergency/ malfunction		Air Boss Pilot, Air Ops, CATCC, SQDN Rep.	Audio-pilot's radio call, Air Boss/Air Ops intercom call	Engine, hydraulic system, flight control, pilot instruments, landing gear, hook, etc.
1.2.5 Landing subsystem functions in operation	SPN-42 (ACLS)	Pilot	Audio-pilot's "meatball" call. Visual-DLC light (S-3 only)	APCS, DLC, ACLS

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
2. <u>ASSESS RECOVERY CONDITIONS</u>				
2.1 Assess environmental conditions				
2.1.1 Ambient light conditions			Visual-ambient light level	Day/night/dusk
2.1.2 Visibility conditions			Visual-fog, haze, ship smoke, rain	
2.1.3 Carrier deck motion	H/R IND. CLASS IND.		Visual-carrier deck movement referenced to horizon, plane guard destroyer	Pitch, roll, heave, yaw
2.1.4 Carrier deck trim	H/R IND CLASS IND.	Air Boss	Visual-carrier deck position referenced to horizon	Pitch, roll
2.1.5 Cloud ceiling		Air Ops	Visual-clouds	
2.1.6 Wind over Deck (WOD) speed and direction	WOD IND.	Air Boss	Visual-ship smoke, ship flags, wake	

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
2.1.7 Horizon			Visual-horizon	Varying levels of definition down to none at all
2.1.8 Plane guard destroyer			Visual-plane guard destroyer or its lights	Approximately one mile aft of carrier
2.1.9 Background noise activity			Audio-engine noises on deck, wind, PA system announcements, radio calls, platform voices	
2.1.10 Sun/moon position			Visual-sun, moon	Positioning can degrade LSO or pilot vision
2.2 Assess condition of landing aids				
2.2.1 Lens basic angle (B/A)	Lens B/A indicator	Air Boss		
2.2.2 Lens roll angle (R/A)	Lens R/A indicator	Air Boss		

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
2.2.3 Deck Lighting		Pilot-for deck lighting satisfaction	Visual-flood lights, runway lights	Drop light visible only to pilot. Air Boss controls lighting.
2.2.4 Lens Operation/ stabilization		Air Boss Pilot		
2.2.5 Approach aids (radar, ICLS, ACLS, TACAN)		CATCC		
2.2.6 MOVLAS		B/U LSO	Visual-observe MOVLAS, MOVLAS repeater	
2.2.7 LSO radio				Radio checks prior to recovery
2.2.8 Lens system brightness	Lens brightness indicators	Pilot-for satisfaction	Visual-evaluation of brightness from platform	Meatball, "red" ball, datums, wave off, cut
2.3 Assess operational factors				

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
2.3.1 Clear/fouled deck status	Clear/ foul deck lights	B/U LSO, Hook spotter	Visual-clear/foul deck light, flags from arresting gear officer (if lights inop.)	
2.3.2 Wire status		B/U LSO	Visual-wires installed, wire position on retraction	
2.3.3 Divert/tanker/ low fuel state situations		Air Boss Air Ops CATCC	Audio-radio comm between CATCC and aircraft, intercom from CATCC	
2.3.4 Ziplip/EMCON condition		Air Boss Air Ops		Operational situation requiring LSO to minimize voice calls
2.3.5 Geographical constraints (sea room, airspace restrictions, near-by terrain)		Air Boss Air Ops		
2.3.6 Pilot skill/ proficiency			Quality of pilot's prior approaches	May be known a priori; CQ pilot, unpredictable; "rusty" pilot
2.3.7 Pilot fatigue			Quality/character of prior approaches	May be known a priori
2.3.8 Operating schedule constraints		Air Boss Air Ops		

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
3. DIRECT PILOT ACTIONS				
3.1 LSO voice transmissions	Radio			Standard (IAW NATOPS) and non-standard phraseology
3.1.1 Informative		Pilot B/U LSO	Aircraft approach parameters & recovery conditions	
3.1.2 Precautionary calls		Pilot B/U LSO	Aircraft approach parameters & recovery conditions	
3.1.3 Mandatory calls		Pilot B/U LSO Air Boss	Aircraft approach parameters & recovery conditions	
3.2 LSO equipment activations				
3.2.1 Waveoff lights	"Pickle" switch	Pilot B/U LSO Air Boss	Aircraft approach parameters & recovery conditions	
3.2.2 Cut lights	"Pickle" switch	Pilot	Aircraft approach parameters & recovery conditions	Used under conditions of radio failure or EMCON/ZIPLIP
3.2.3 MOVLAS operation	MOVLAS control and repeater	Pilot B/U LSO	Aircraft approach parameters & recovery conditions	Backup system to lens (FLOLS); also used when deck motion exceeds lens stabilization limits

TASKS	JOB AIDS	PERSONNEL INTERACTIONS	CUES	NOTES
4.0 ADVISE SUPERIORS OF RECOVERY FEASIBILITY, EFFICIENCY AND SAFETY				
4.1 Aircraft problems		Air Boss CATCC SQDN Rep Air Ops	Various (described earlier)	
4.2 Environmental Conditions		Air Boss CATCC	Various (described earlier)	
4.3 Condition/status of landing aids		Air Boss CATCC	Various (described earlier)	
4.4 Operational factors		Air Boss CATCC Air Ops	Various (described earlier)	

APPENDIX B

LSO INTERFACE

There was comprehensive interface with the LSO community during this project. A formal briefing was conducted with LSOs to stimulate group discussions of the LSO job and LSO training needs. Five briefing sessions were conducted:

1. NAS Miramar, November 1977 — CNAP LSO and representatives from the F-14, F-4, and A-7 communities; Readiness Squadron and Air Wing LSOs.

2. NAS Miramar, December 1977 — Representatives from the F-14 and E-2 communities; Readiness Squadron and Air Wing LSOs.

3. NAS North Island, January 1978 — CNAP LSO and representatives from the S-3 Readiness Squadron.

4. NAS Pensacola, January 1978 — Phase I school staff and students, CNATRA LSO and representatives from Training Wings and Training Squadrons; TA-4 and T-2 communities represented.

5. NAS Oceana, January 1978 — CNAL LSO and representatives from the F-4, A-6, A-7, E-2 and RA-5 communities; Readiness Squadron and Air Wing LSOs.

Interaction with individual LSOs included significant communications with the type commander LSOs (CNAL, CNAP and CNATRA) as well as additional LSOs from the F-4, F-14, S-3, A-6, EA-6 and F-8 communities. Including the group and individual discussions and the questionnaire responses, there was interface with approximately 100 LSOs.

APPENDIX C
CARRIER LANDING ACCIDENT SURVEY
(JULY 1970 thru DECEMBER 1977)

An analysis was made of carrier landing accidents over a recent eight-year period, using a computer survey from the Naval Safety Center. One hundred and forty-three accidents were reviewed in the printout, which was examined for Landing Signal Officer involvement in any given instance. The results of this analysis appear below, but two problems were encountered during review of the data and deserve mention here. First, there seems to be a lack of standardization in narrative format for accident reporting. Treatment of all parties in the carrier landing environment (e.g., Air Boss, LSO, platform assistants, etc.) is uneven across the report readout. Some narrative descriptions give almost superfluous attention to LSO actions prior to the accident while others omit any mention of the LSO in what appears to be parallel circumstances. Although this only occurs when the LSO is not a contributing factor, the reasons for treatment in one case and exclusion in another are frequently confusing and the reader is left with doubt regarding the significance of passing mention of the LSO. Second, standardization of causal/contributing factors summaries also leaves something to be desired. The conclusions of accident narratives may be divided into causal and contributing categories, contributing factors alone, or simply, factors. Although most narratives are easily analyzed, those with a single conclusion category require the reader to revert to the body of the synopsis to establish (or otherwise infer) relative involvement of parties.

Of the accidents reviewed in the Naval Safety Center report, LSOs were at least mentioned in 98, or 69% of the total number of narratives related.

LSO MENTION

LSOs were mentioned in other-than-contributing status in 50, or 35% of the accident total. The reasons for such mention are cited below, in descending order of frequency:

No response to LSO control — 33 reports (66%). These accidents involved approaches in which the LSO took proper action, within his range of ability and authority, but response by the pilot/aircraft was either insufficient or lacking entirely. It would appear that little could be done regarding LSO training to alleviate such problems, which were almost entirely attributed to pilot error. However increased LSO task effectiveness would probably increase pilot confidence in the LSO.

LSO grade reports — 7 reports (14%). Narratives in this category reviewed LSO pass grades for previous approaches (bolters or wave-offs in the case of pilot error) or for the accident approach (in the case of material failure), in order to clarify the quality of pilot control or the environmental circumstances surrounding the accident against a presumably expert criterion (the LSO). Other than emphasizing the importance of accurate, objective LSO evaluation, this category has minor relevance to LSO quality or training.

Environmental factors — 4 reports (8%). Accidents attributed to environmental causes, such as unusual deck pitch rates, irregular deck winds, etc. In these instances, it was implied by the explanation of LSO action that little could have been done from the platform to have prevented the accident in question (e.g., a sudden deck rise as the aircraft crosses the ramp, unexpected from the prevailing pitch cycle, which results in a hard landing). Increased LSO training and/or experience might improve the scope or rate of LSO scan patterns, but advocacy of this point would have to await further analysis.

Communication problems — 3 reports (6%). These accidents involved cases in which LSO control or advisory transmissions were not received or were misunderstood by the aircrew or were confused with communications inside the cockpit. No LSO fault was implied by any of these reports and it would appear that little could be done by the LSO to reduce such incidents.

Material failure — 3 reports (6%). Narratives in this category assigned aircraft or deck equipment material failure as the causal factor in the accident. LSO description involved brief histories of transmissions given prior to the accident; no LSO performance was questioned, and no corrective recommendations were listed or implied.

LSO INVOLVEMENT

LSOs were listed as contributing factors in 39 cases, or 27% of the accident total, and were cited as causal factors in 9 cases, or 6% of the total. Essential background data are summarized below:

Time of recovery —	Night	28 reports	(72%)
	Dusk	1 report	(2%)
	Day	10 reports	(26%)
Aircraft type —	A-7	11 reports	(28%)
	F-8	7 reports	(18%)
	F-4	7 reports	(18%)
	A-4	4 reports	(10%)

A-5	4 reports (10%)
A-3	3 reports (8%)
F-14, A-6, E-1	1 report each (8%)

Failure to give timely waveoff — 17 reports (35%). These reports attributed contributing or causal responsibility to the LSO for failure to wave off an unsatisfactory approach, or failure to give the wave off in sufficient time to be effective. This is obviously a critical responsibility of any LSO and the faculty for judging the necessary waveoff point for an approach can be greatly enhanced through training and experience. It should be stated however, that almost any subsequent landing accident might have been prevented had the approach been aborted by an LSO waveoff decision, so appearance of this factor in an accident report is not necessarily diagnostic of genuine LSO fault. It is good insurance in accident investigation to include the caveat that a waveoff would have prevented subsequent tragedy, and at least one report in this series cited the academic possibility of LSO waveoff in an accident otherwise exclusively assigned to pilot error.

Insufficient/incorrect LSO control — 16 reports (33%). This other major factor in LSO accident involvement listed various actions of approach control that were required and not given, that were given too late, or that were inappropriate to the given flight situation. Due to the brief nature of the accident summaries, it was not possible to establish patterns of control problems, or the reasons behind them. Thus, the failure to transmit a required correction by the LSO might have been due to perceptual failure, judgment flaw, or both. LSO training and experience would improve performance in either of these areas, however, so the overall problem would seem subject to corrective action.

Procedural/judgment deficiencies — 11 reports (22%). Failure to appreciate the situational variables involved in a recovery (e.g., technique changes for pitching deck, crosswind, or aircraft emergency) or to know the explicit procedures to follow in the situation were listed in this category, as were failures by supervisory personnel (i.e., senior LSO on the platform) to take command when the controlling LSO was not performing properly. Knowledge of specific procedures, as well as situational judgment were included here, both of which are vulnerable to improvement through increased training.

Administrative/debriefing factors — 3 reports (6%). These narratives listed insufficient debrief of weak pilots (prior to the accident) by the waving LSO, failure to ensure that subsequent improvement took place among counseled pilots, or premature carrier qualification of pilots by LSOs. Corrective measures are many for this problem, but the principal benefit of relating this factor is to point out the broad scope of LSO responsibility to carrier landing safety.

Fatigue or limited capacity — 2 reports (4%). Accidents which might have been prevented by more attentive control were listed in this category. In the reports surveyed here, the LSO was mitigated by circumstances of extraordinary time spent on the platform or without sleep. As such circumstances are frequently out of LSO control, it would seem that little could be done to alleviate the problem with further training.

SUMMARY

Many of the problems which contributed to the landing accidents in the survey could be significantly reduced by more extensive LSO training or further exposure to the platform environment, but some of the factors (e.g., fatigue) are not so easily handled. An additional observation should be offered that bears directly on the LSO training problem. Beginning with the accident summary for 1975, a few narratives discuss the ramifications for safety of low flight operations tempos. It appears that safety problems are apparent in reduced operational rates and have been realized by accident boards from the beginning of the reduction, which is encouraging for the objectivity and balance of these reports.

APPENDIX D

LSO VOCABULARY

STANDARD (From LSO NATOPS):

INFORMATIVE CALLS

Used to inform pilots of existing situations.

TRANSMISSION	MEANING	RESPONSE (Aircraft in Manual Mode)	RESPONSE (Aircraft in APC Mode)
"You're (a little) high."	Aircraft is (slightly) above optimum glide-slope.	Adjust sink rate with power/nose attitude to establish center ball.	Adjust sink rate with nose atti-tude to estab-lish center ball. (Avoid using in close.)
"You're (a little) low."	Aircraft is (slightly) below optimum glide-slope.	Adjust altitude immediately.	Adjust altitude immediately.
"You're going high (low)."	Unless correct-ed, aircraft will go above (below) optimum glideslope.	Adjust sink rate with power/nose attitude to maintain center ball.	Adjust sink rate with nose atti-tude to maintain center ball.
"You're lined up left/right."	Aircraft has undershot/over-shot centerline.	Reestablish centered line-up.	Reestablish centered line-up.
"You're drifting left/right."	Aircraft is drifting left/right of center-line.	Correct lineup to centerline.	Correct lineup to centerline.
"You're fast/slow."	Self explanatory.	Adjust nose attitude/power to establish optimum AOA.	Not used.
"Roger Ball" (AUTO/MANUAL/Coupled as appropriate)	LSO acknowl-edges pilot meatball acquisition.		
"Paddles Contact"	LSO assuming control from CCA.		

PRECAUTIONARY CALLS

Used to direct pilot's attention to potential difficulties and prevent possible control errors.

TRANSMISSION	MEANING	RESPONSE (Aircraft in Manual Mode)	RESPONSE (Aircraft in APC Mode)
"Check your lineup."	Aircraft lineup is not optimum.	Correct lineup drift or position.	Correct lineup drift or position.
"Don't settle"-"Don't go low."	Aircraft will settle below optimum glide-slope if not corrected.	Check sink rate and meatball to avoid settling below glide-slope.	Check sink rate and meatball to avoid settling below glide-slope.
"Don't climb"-"Don't go high."	If not corrected aircraft will climb above optimum glide-slope.	Check sink rate and meatball to avoid climbing above glide-slope.	Check sink rate and meatball to avoid climbing above glide-slope.
"Keep your nose up"-"Hold your attitude."	Pilot tends to drop nose.	Don't drop nose.	Don't drop nose.
"Hold what you've got."	Self explanatory.	Hold present (optimum) stick and throttle positions.	Hold present (optimum) stick position.

IMPERATIVE CALLS

Used to direct pilot to execute a specific control action.
MANDATORY IMMEDIATE RESPONSE.

TRANSMISSION	MEANING	RESPONSE (Aircraft in Manual Mode)	RESPONSE (Aircraft in APC Mode)
"A little power."	Aircraft is decelerating; unless corrected aircraft will become slow/low.	Correct with power.	Call not used.
"Power."	Aircraft is low/slow.	Add power.	Add power and disengage APC. Refer to Note.
"Go Manual."	Disengage APC.	Not Used.	Add power and disengage APC. Refer to Note.
"Attitude"-(A little attitude.")	Aircraft nose is low/flat attitude.	Increase nose attitude (slightly).	Increase nose attitude (slightly) to reduce sink rate.
"Right/Left for lineup" (Use in close or at the ramp.)	Aircraft will land left/right if not corrected.	Correct lineup to centerline, then level wings.	Correct lineup to centerline, then level wings.
"Bolter."	Self explanatory.	Add 100 percent power and execute bolter in accordance with model NATOPS manual.	Add 100 percent power and execute bolter in accordance with model NATOPS manual.

IMPERATIVE CALLS (Cont)

TRANSMISSION	MEANING	RESPONSE (Aircraft in Manual Mode)	RESPONSE (Aircraft in APC Mode)
"Waveoff" or "Waveoff, Foul deck" (Whenever waveoff lights are keyed.)	Self explanatory.	Execute waveoff in accordance with model NATOPS manual.	Execute waveoff in accordance with model NATOPS manual.
"Cut."	Release signal, as necessary to landing.	Response mandatory for all prop landings and jet barricade engagements.	Response mandatory for barricade engagements.
"Speedbrakes."	Speedbrakes are extended.	Retract speedbrakes.	Retract speedbrakes.
"Extend Speedbrakes."	Self explanatory.	Comply.	Comply.
"Drop your hook."	"	"	"
"Drop your gear."	"	"	"
"Drop your flaps."	"	"	"
Uncouple.	Disengage ACLS.	Disengage ACLS.	Disengage ACLS.

NOTE: Aircraft is considered to be in manual mode immediately after this call. Manual calls/responses are subsequently applicable.

NONSTANDARD:

Hold it up (you're not settling, but you're about to)
Fly the ball (pay attention to glideslope, now that you've corrected some other deviation; make your play; don't go high, or don't go low; etc.)
Don't climb (make your play; don't go through it; etc.)
Fly it on down (make your play; etc.)
That's it (follows a sequence of corrective calls by the LSO, when he feels that the response is taking effect and is trying to avoid the development of an overcorrection; and LSO "comfort" call, as much for his benefit as for the pilot)
Call the ball (when the LSO has not heard the expected pilot call)
The deck is moving (warning; modify glideslope control technique accordingly; be prepared for more frequent LSO assistance; pay close attention to LSO calls)
Catch it (stop the impending deviation or overcorrection)
Stop it in the middle (prevent deviation or overcorrection with centered ball)
Don't go through it (similar to above)
Nice and easy with the power (suggested modification of technique)
You're settling (similar to "you're going low")
You're underpowered (statement of pilot trend, impending slow or low deviation)
Pick it up (climb back to glideslope from low position; i.e., "you're low")
The deck's down — hold what you've got (don't react to deck motion or meatball movement)
The deck's steady — good ball (meatball information is correct)
You're working a little low (glideslope position is consistently low)
Still low (pilot has failed to correct/respond to demand for correction)
Ease it down (aircraft is high, LSO does not want overreaction)
Start it down (pilot is high at start or has not corrected for high ball)
Work it off nice and easy (pilot is high; LSO caution for gentle correction)
Start it back to the right/left (call for line up correction)
You're low — pick it up (self-explanatory; increase in imperativeness from "you're low")
Don't decel (aircraft is/may be going slow)
Fly it down (high or going high; make your play; stay on glideslope to touchdown; etc.)
Don't drop your nose (an attitude call; frequently used when pilot has rough attitude control)
Don't chase the ball (comment on moving deck, in which case a steady pass control is preferred to following unreliable meatball)
Get it back up (correct up to glideslope)
Work it up (climb up to glideslope, but with gradual power control)
Center the ball (get on glideslope)
Put it on glideslope (same as above)
A little left/right for lineup (self explanatory)

APPENDIX E

LSO TRAINING SYSTEM SYLLABUS

Levels of Achievement and Blocks of Training

The levels of achievement for the Automated Adaptive LSO Training System are described below in narrative form. The sequential ordering of the levels is grouped into blocks of training that serve to organize the myriad.

Block One

Block One is an introduction and overview of the training system. Included in this presentation is a description of the visual system, the work station, the speech recognition, performance evaluation and adaptive syllabus.

Block One - Level One

Level one consists of an orientation to the job of the LSO and an overview of the training system. Included in the overview will be a brief description of each topic to be covered in Block One.

Block One - Level Two

The visual system is explained in Level Two. The student is presented with a brief description of CGI and given an explanation of what is expected of him as the student utilizing the visual system.

Block One - Level Three

The speech recognition is the subject of Level Three. Again the student is given a brief functional description of the system and an explanation of what is expected of him when using this system.

Block One - Level Four

Level Four focuses on the simulated workstation. The introduction will concentrate on the manner in which the system presents the job aids and the consequences of the representation for him as a functional LSO.

Block One - Level Five

The student is provided with a description of the performance evaluation system in Level Five. In Level Five, the student is also introduced to the concept of an "ideal" or "model" LSO. It will be further explained that his performance will be compared with the "model" LSO throughout the training system and that feedback will be provided concerning his performance progress. In addition, the concepts of a call envelope and a waveoff envelope will be introduced as the system introduces the "model" LSO.

Block One - Level Six

The adaptive syllabus is explained in Level Six. The relationship of the adaptive syllabus and the performance evaluation system will be the major focus of this level. The advancement and remediation techniques will be fully explained in relation to the performance evaluation system. The adaptive nature of the logic will not be a complete mystery to the student. He will know what to expect and when to expect it.

Block Two

The basic LSO skills are introduced in Block Two and the student is given sufficient practice to develop the skills to a reasonably automatic level. The deviation that the student is exposed to requires an immediate corrective call or waveoff. The calls that the student learns, for this block, are the calls labeled informative in the NATOPS manual. During this block an idealized situation is presented to the student where the aircraft he is observing responds to his calls in a perfect manner. For example, if the aircraft deviates left of course and the student calls "you're lined up left," the aircraft will then return to the ideal course at a normal rate.

In addition, Block Two will be conducted under "perfect" weather conditions. There will be no extraneous factors to complicate the aircraft's approach and hence the student's job as LSO. We are describing a situation where the student can concentrate on the perceptual and verbal aspects of this minimal LSO control situation without the complicating factors that are typical to the "at sea" environment. Given below is breakdown of the basic LSO job into individual skills that are addressed individually in a serial manner before they are composited into a multidimensional perceptual task. The focus of this block of training is to introduce the ideal wave-off window and the relationship of the call window to the wave-off window. In addition, the student will be required to develop a perceptual scheme for each of the windows that he can build on as a foundation for the development of additional skills.

Block Two - Level One

Level One is the student's initiation to this training block. It includes the following topics:

a. An overview of the material to be presented in this block

b. An introduction to the radio terminology used during the block

c. An explanation of the waveoff window and how it is generated

d. An explanation of the call window including some of the possible dynamic aspects of this window

e. Introduction to the handoff from CATCC

f. Practice accepting handoffs and making waveoff calls when the aircraft violates the waveoff window, so that the student begins to understand the dynamics of the waveoff window as a function of distance

g. An explanation of the performance measurement system as it relates to student feedback and course advancement

Block Two - Level Two

In Level Two the student is introduced to glideslope deviations and the radio terminology used to communicate the presence of the deviation to the pilot. Glideslope is chosen as the initial training task because interviews with fleet LSOs indicate that glideslope is a relatively easy deviation to detect. Given this low level of difficulty the student is quite likely to perform this task successfully and therefore increase his confidence in both himself and in the system.

Block Two - Level Three

Detecting line-up deviations is the skill that the student must master in Level Three. Based on our interactions with LSOs it seems appropriate to introduce lineup quite early in the syllabus because of the difficulty the student is likely to have in mastering this task. The student is likely to find that line-up deviations are the most difficult perceptual skills to be developed and his performance will be enhanced by practicing this skill as much as possible.

Block Two - Level Four

The interaction of glideslope and lineup is presented in Level Four. The interaction is presented graphically and verbally. In addition, the student is given considerable practice in making glideslope and line-up calls. This is done so that the student will arrive at a functional understanding (discover the appropriate invariants and their peculiar affordance (Gibson, 1976)) of the relationship between the two factors. Our interviews with fleet LSOs indicated that detection of these composite deviations is very difficult, suggesting that we should pay particular attention to this problem when we design the training system.

Block Two - Level Five

Like Level Four training, Level Five is concerned with the interaction of two simple deviations. Again the composite interaction is a complicated combination of the two deviations, in this case glideslope and angle of attack (AOA)/ airspeed. AOA is introduced at this time due to its functional interrelationship to glideslope. Syllabus considerations were predicated on logic similar to that described in Level Four.

Block Two - Level Six

Level Six is the final level of achievement in Block Two. In this block all the deviations and R/T learned in the previous five levels are consolidated and treated simultaneously during an approach. Again practice is viewed as the key to student success and it will be during the final phase of this level of achievement where the student demonstrates the automaticity of his new repertoire and his baseline β level for ideal conditions is calculated. Later in training we will attempt to modify this baseline β level to get a clear indication of where the subject is setting his response bias criterion.

Block Three

Block Three is designed to expand the basic LSO skills developed in Block Two. The first topic considered in this block is the introduction of the remainder of the standard LSO R/T, the precautionary and imperative calls. These calls are introduced in relation to the aircraft's distance from touchdown and the criticality of the calls made at the "in close" position is emphasized. The dynamic aspects of the windows are also emphasized during the early levels of the block. During the last three levels of training the focus is on changes in the rate of deviation and their effects on the call window. Again, the pedagogical procedure used is to present changes in rate of deviation for both lineup and glideslope separately, followed by a training session devoted to a combination of both of these deviations. When the student completes this block of training, he will have mastered the perceptual and verbal skills necessary to wave a particular type of aircraft, under ideal conditions during a simple aircraft recovery.

Block Three - Level One

The student is presented with an overview of the material to be presented in this block and a brief review of Block Two. The topics introduced in Level One include:

a. the remainder of LSO R/T
   - Precautionary calls
   - Imperative calls
   - Informative calls (review)

b. The relationships of call type to distance to touchdown (stated in terms of criticality of the call)

c. The dynamics of the windows as a function of distance to touchdown and rate of direction

d. A further explanation of the performance measurement system as it applies to this block of training.

Block Three - Level Two

In Level Two the student is presented with the R/T he will commonly use when an aircraft is "in the middle." In this level, changes in deviations occur only during the initial portions of an approach where informative and precautionary calls are used. The ideal pilot/aircraft model is used so the student's calls are immediately heeded. The precautionary calls are introduced before the imperative calls because the size of the deviations associated with the precautionary calls is generally much larger and hence easier for detection response. The successful completion of this level of achievement should result in bolstering the confidence of the student and increase both the amount of effort he will apply to later tasks and the degree of satisfaction he will derive from the training session.

Block Three - Level Three

Level Three is concerned with the introduction of imperative calls. The use of imperative calls is tied to the criticality of the situation to successful completion of a safe approach. During a normal approach the LSO usually makes imperative calls only when the aircraft is "in close" to the landing area, where small deviations are of considerable importance to the safety of the aircraft. Given the relationship of distance to touchdown and the size of an acceptable deviation the system will emphasize the perceptual aspects of determining the distance to touchdown and hence the appropriate use of imperative calls.

Block Three - Level Four

Prior training has introduced only one situation influencing the size of the call window, the aircraft's distance to touchdown. Level Four introduces a new factor that constrains the size of the call window. The size of the window used in the previous block and levels has been an ideal window for situations involving ideal weather, pilots, aircraft, etc. In this level we are going to complicate the picture somewhat. The rate of glideslope deviation, constant and "ideally normal" previously, will be allowed to fluctuate. The student will be made aware of these fluctuations and their effects on the call window and hence his performance as an LSO. His performance will be measured in a fashion similar to that used in Block Two.

Block Three - Level Five

Like Level Four where the rate of glideslope deviation was allowed to fluctuate, Level Five is also concerned with fluctuations in the rate of deviations. The deviations in Level Five are with respect to lineup and the conditions and situations expounded in Level Four hold in Level Five.

Block Three - Level Six

Level Six is where we "put it all together." Previous levels have been concerned with fluctuations in the rate of deviation along single dimensions. Simultaneous changes in the rate of deviations for both lineup and glideslope occur in Level Six. We intend that the student learn to abstract perceptual cues that are indicative of these simultaneous deviations irrespective of the individual rates of deviation. After the student completes the third phase of this level he should have mastered the basic skills of waving a particular type of aircraft under a very limited set of conditions.

Block Four

Block Four is the first of five blocks that introduce the student to situations that he is likely to encounter while "at sea." In addition, the student will be introduced to several of the LSO workstation job aids during these blocks.

When describing the training situation for all levels of training that follow the only factors that will be noted are factors that are different from those described or implied in the level that was just completed.

More specifically, Block Four is an introduction to the more subtle and complicating conditions of a recovery such as dark night recoveries and multiple aircraft recoveries.

Additionally, a number of problem causing situations that will have impact on the student's performance will be introduced.

Block Four - Level One

During this level the student receives an overview of the conditions and situations he will encounter during Block Four. The most drastic conditions he will face during this block are dark night recoveries and multiple aircraft recoveries. The situations he will encounter are detailed in the next five levels of achievement. The student is also introduced to six job aids, the lens setting indicators, the foul deck/clear deck indicator, the Wind-Over-the Deck (WOD) indicator, the PLAT, SPN-44 and SPN-42.

Block Four - Level Two

Due to the large number of job aids introduced in Block Four, Level Two will consist of a number of recoveries where the student will be allowed to use the new equipment. The situations and conditions the student will encounter in this level are situations and conditions he has encountered previously in the other training blocks. The student is expected to become proficient in the use of these job aids during the block.

Block Four - Level Three

Two common situations are introduced in Level Three, gross start deviations and unusual pilot responses. Gross start deviations refer to deviations that occur during the handoff from CATCC and to deviations that are due to bad CCA starts. These deviations may be of any type and some are severe enough to require an immediate corrective call. Unusual pilot responses are unexpected responses that jeopardize the safety of the approach or indicate a trend toward a risky approach.

The LSO is expected to respond to this situation by narrowing his call window for the rest of the approach.

Block Four - Level Four

Level Four includes a triplet of situations aboard the aircraft that affect the LSO's performance or the approach itself. The first situation involves unusual aircraft configurations that affect both the aircraft's approach and the LSO's ability to control the approach. The approach is typically affected by increasing the aircraft's airspeed, thereby decreasing the probability of a safe landing and making the LSO's job more difficult due to the resultant decrease in approach time (less time means fewer calls possible) and the shrinking of the call and wave off windows.

At night the only reliable cues to the aircraft's position and attitude are the lights on the aircraft. The second situation involves aircraft with light system malfunctions, thereby depriving the LSO of a basic perceptual cue. The student is exposed to this situation by presenting him with three lighting problems, an inoperative AOA light, AOA lights that are incorrect and aircraft with one of its wing lights out. The third and last situation explored in this level involves moderate crosswinds that continuously push the aircraft off line-up making the LSO's line-up perceptions and calls extremely important.

Block Four - Level Five

Level Five includes several situations during which the pilot loses visual feedback of one form or another and the LSO must provide the pilot with the information he normally receives from the visual scene. An incorrect lens setting or an abnormally large glideslope deviation will deprive the pilot of glideslope information and the LSO must then supply that information.

Smoke in the groove is another visual problem that is perhaps more serious, since the pilot is deprived of all visual cues during a portion of the approach. Unfortunately, the LSO is also deprived of his visual cues in this situation. The situation is handled by having the aircraft well set up prior to encountering the smoke and by being prepared for a large deviation upon exit from the smoke.

Block Four - Level Six

Common deck conditions that affect the recovery of the aircraft are presented in Level Six. The LSO's indication of deck condition is the foul deck/clear deck lights. There are two deck conditions addressed in this level, foul deck during an entire approach and a foul deck indication after receiving clear deck information during the initial portions of the approach. The situation that incites the above mentioned conditions includes a slow retracting wire and activity on the deck. A slow retracting wire during an approach will cause a delay in getting a clear deck signal and hence will require the LSO to make a decision about when (where) to waveoff the aircraft. Activity in the landing area during an approach will have a similar impact on the LSO. Noise on the deck impacts the recovery by presenting the LSO with an annoyance that may interfere with his concentration and may potentially impact the recovery.

Block Four - Level Seven

Radio problems are the subject of Level Seven. Five types of radio problems are focused upon: CATCC fails to change LSO radio frequency, a priori knowledge of a radio failure, radio failure that occurs on approach with no warning, intermittent failure of the radio and ziplip exercises. In all of the situations listed above the LSO must use the pickle (cut lights) to control the approach.

Block Four - Level Eight

Level Eight addresses the problem of controlling aircraft that are flying automatic approaches. There are three automatic systems that can be used during an approach, direct lift control (DLC), automatic power compensation (APC) and the automatic carrier landing system (ACLS). DLC affects the pilot's response style and has minimum impact on LSO performance. APC keeps the aircraft on speed during the approach. When an aircraft is using APC, the LSO uses a power call only for the grossest of deviations. In addition, once the LSO makes a power call the pilot is required to switch to manual control of the power setting. There are two modes of operation available when using the ACLS. Mode I is a landing procedure that uses the automatic mechanism all the way to touchdown. During a Mode I approach the LSO must be vigilant about watching for deviations since it is possible for the system to fail without warning and it is possible that the pilot will not detect the problem. Mode I A is the other means of using the ACLS system. Here the pilot switches to manual control at 3/4 miles. When the aircraft reaches the 3/4 mile mark, it should be closely aligned for the approach. However, when the pilot takes over, he is not operating in the proper context and it will take some time for him to establish his usual complete and fine tuned control of the aircraft. During this period of adjustment deviations in alignment may occur and the LSO must expect these deviations.

Block Four - Level Nine

In the operational world of the LSO, job aids are frequently inoperative for one reason or another. In Level Nine the student is introduced to these malfunctions and required to rely on his basic perceptual abilities rather than the support of the job aids.

Block Five

In Block Five the student is exposed to situations that require an extreme or drastic change in the student's call window. The general operating conditions found in this block include all the conditions found in Block Four. In addition, in Level Five, we will introduce a moving deck condition that will complicate the LSO's job considerably.

Block Five - Level One

Level One is an overview of the situations that will be encountered during this block of training. Special attention will be given to deck movement conditions and their impact on the LSO's call window. Two new job aids will also be introduced to the student and he will be given an opportunity to use each of them as their functions are explained by the system. The job aids are the Hook-to-Ramp indicator and the MOVLAS.

Block Five - Level Two

Three situations that degrade pilot performance by reducing the availability of certain types of information are introduced in Level Two. The LSO must compensate for the loss of information by verbally providing the major aspects of the information to the pilot. One of the situations involves a loss of deck lighting, specifically, the runway lights or the drop lights, which deprive the pilot of line-up cues which the LSO must then provide. The second situation, a malfunction of the flood lighting on the deck, deprives the pilot of the textual cues that he uses during the later portions of the approach. Again, the LSO is expected to compensate for the loss with appropriate use of voice calls. The last situation encountered in this level is a malfunction of the precision radar system. This malfunction deprives the pilot of information necessary for proper alignment at the start of his final approach. The LSO must compensate for this problem by transmitting calls that help the pilot return to proper alignment.

Block Five - Level Three

The LSO relies on a set of perceptual cues that allow him to locate the aircraft in space and determine the relation of the aircraft to the carrier deck and to other features of the environment (e.g., the water). In Level Three, we will deprive the LSO of two of his more useful cues to these relationships, the horizon and the plane guard destroyer.

Block Five - Level Four

Wind conditions have a large effect on aircraft recoveries. Level Four presents three wind conditions that have a significant effect on the recovery and on the LSO's task. The WOD indicator will become an important job aid in this level. WOD problems entail primarily the extremes of the velocity continuum, excessive wind over the deck and minimum wind over the deck. Strong crosswinds also affect the aircraft, hence the LSO must take the wind into account when making his calls.

Block Five - Level Five

Level Five presents the student with deck movement conditions. The job aids that are used during severe deck movement conditions, the Hook-to-Ramp indicator and the MOVLAS, were introduced during Level One under steady deck conditions. The student's skill with these aids will be expanded in Level Five under severe movement conditions. Trim states will also be addressed in this level as well as a ship turning situation. The final situation to be introduced in this level is a combination of all movement conditions and a malfunction of the job aids.

Block Five - Level Six

Two emergency situations are addressed in Level Six, an aircraft with an engine out and a barricade recovery. The LSO must adjust his waving strategies for each emergency.

- Aircraft with engine failure - changes in LSO control parameters ("windows"), familiarity with aircraft performance characteristics with single engine, effects of deck motion and MOVLAS utilization.

- Barricade recovery - changes in "window," changes in glideslope geometry, changes in voice calls, pilot pre-briefing.

Block Six

The previous blocks have all been concerned with recovering but a single type of aircraft. Block Six presents the student with a variety of aircraft to wave. The student has become quite proficient at waving and should be ready to expand his waving repertoire to include a number of aircraft types. The block is sequenced so that the student can concentrate on a single type of aircraft at one time, progressing from single aircraft recoveries to multiple aircraft recoveries of a single type of aircraft. Once the student has become proficient in waving all types of aircraft, he will be required to wave a multiple aircraft recovery containing all different types of aircraft.

Block Six - Level One

The student has been waving a single type of aircraft in the previous blocks. The type of aircraft he normally flies will probably be the first new aircraft he will be introduced to, followed by the rest of the types in ascending order of waving difficulty. The introduction of each new type of aircraft will include a description of the aircraft's flight dynamics and an explanation of the relationship of these dynamics to LSO waving strategies. In addition, the student will be given practice in waving single aircraft recoveries of each type of aircraft.

Block Six - Level Two

Level Two is an expansion of Level One to include multiple aircraft recoveries of a single type of aircraft. The type of aircraft will be changed from recovery to recovery until the student becomes adept at waving all types of aircraft. Practice is the key to success in Level Two. The situations that the student encounters in Level Two are only those situations from the previous blocks that bear directly on the type of aircraft being waved.

Block Six - Level Three

All types of aircraft are encountered in the multiple aircraft recoveries presented in Level Three. Again, practice is the focus of Level Three. In addition, Level Three may present the student with any of the situations he encountered in the previous blocks of training.

Block Seven

Block Seven is for the most part a consolidation period for the student. In this block, he encounters situations that are unusual and typically only handled by experienced Wing Category LSOs. Any of the conditions presented in earlier blocks of training may occur in Block Seven. There are two other pieces of equipment that are presented to the student in this block, the HUD (a heads up display system) and CLASS (a sophisticated FLOLS indicating and stabilization system).

Block Seven - Level One

Level One is an overview of the situations found in this training block and an introduction to the HUD and CLASS job aids.

Block Seven - Level Two

The student practices using the HUD and the CLASS during Level One. A wide variety of situations and conditions can be presented to the student during this level including most specifically situations in which he has performed poorly and situations in which he performed very well.

Block Seven - Level Three

During Level Three the pilot experiences problems with the visual feedback he receives from the lens and the LSO must compensate for this lack of glide-slope information. The first situation presented involves a loss of the lens during the approach due to a malfunction of some sort. In this situation the LSO must talk the pilot down. The second situation involves a lens that is too bright or dim. The LSO ensures that the setting is adjusted in accordance with the pilot's advisory, while giving the pilot additional assistance. The third situation involves the context that is set for the LSO by a series of consistently high or low approaches. The situation evolves from a lens that is out of calibration and the recognition of this fact is what we would like the LSO to deduce from the situation.

Block Seven - Level Four

An adverse weather problem is presented in Level Four. In this situation the aircraft breaks out of clouds (low ceiling or fog bank) at less than 3/4 miles. This is a difficult situation for the LSO because it is harder to generate an expectancy for the type of call he must make.

Block Seven - Level Five

Three aircraft emergencies are addressed in Level Five. In each case the emergency affects the LSO by limiting the type of control maneuvers the aircraft can make. The emergencies are aircraft engine failure and flap blow-up occurrence "in the groove" and flying an approach with flight control problems.

Block Seven - Level Six

Job aid malfunctions are the topic of Level Six. Actually, the malfunction of a job aid should not affect the LSO's performance. He should be able to do the job without it. The radio and the pickle are the two job aids that perhaps could be considered exceptions to the statement above. Radio failure has been specifically introduced earlier in training leaving pickle malfunction to be trained here. In addition, malfunctions of the HUD and the CLASS are also presented.

Block Eight

The situations addressed in Block Eight are designed to put pressure on the LSO to get the aircraft aboard. Block Eight is designed to give the student an idea of the maximum window sizes he can employ in making his calls under some of the most intense pressures he will encounter.

Block Eight - Level One

As usual the first level of the block serves as an introduction, giving the student an overview of the block. The situations covered in the block are previewed and the student is told exactly what is expected of him in each situation. All situations presented in this block may occur in conjunction with any of the situations presented in earlier blocks.

Block Eight - Level Two

Level Two introduces situations that bear directly on the safety-efficiency tradeoff. These situations involve circumstances where the effect of not getting the aircraft aboard decreases the probability of recovery during subsequent approaches. To handle these situations the LSO will modify his safety-efficiency tradeoff criteria, biasing his decisions and actions toward recovery efficiency. By trading a portion of the approach safety of the immediate approach for increasing safety of the subsequent approaches he will increase the probability of safe recoveries for the recovery in general.
Level Two consists of four situations that affect the safety-efficiency tradeoff: a low-fuel state aircraft, subsequent aircraft in the pattern that have low fuel states, no tanker in the air and a long divert for bingo field (or no divert) and the ship is running out of sea room or running into weather (fog bank).

Block Eight - Level Four

Problems with the pilot in the aircraft being recovered is the subject of Level Four. The most serious problem is the pilot with vertigo requiring an LSO talk down. The pilot with a record of repeated poor approaches during a single recovery is another pilot problem the LSO must face. The appropriate response for the LSO in this condition is to shrink his call window thereby helping the pilot stay closer to the ideal approach pattern. The last pilot problem encountered in Level Four is a general problem of a night CQ operation where the LSO is encountering a series of unpredictable approaches.

Block Eight - Level Five

The difficulty of a recovery is increased when the LSO's visual cues are partially or completely eliminated. In Level Five, the LSO is confronted with two extreme instances of minimal visual cues. The aircraft is presented with no (zero) lights or only one light during a night approach.

Block Eight - Level Six

Job aids or recovery equipment malfunctions are covered in the two situations presented in Level Six. The first situation involves a situation where both the lens and the MOVLAS fail. The second situation finds a wire missing and the LSO manipulating his call window to compensate for it.

APPENDIX F

CARRIER LANDING SCENARIO VALIDATION

A validation study was run with the LSO training syllabus, using four LSOs as subjects in a paired-comparison design. Scenarios were synthesized from the situational variables of the syllabus, each containing three pieces of redundant information (the nature and prevailing conditions of the recovery) and two pieces of unique information (distinct problems or conditions of the aircraft and/or deck). Each LSO independently sorted a subset of these scenarios along a difficulty scale, using a printed sheet of instructions as a guide. After the sequence was recorded, each LSO recorded which piece of information he thought contributed the most to a given scenario; i.e., which factor made the scenario as difficult as it was and played the major role in his decision for rating it as he did. Sufficient overlap in variables, including provision for anchor points, was designed into the study to allow accurate inter-list comparison. Subset lists of scenarios were divided in such a way that two LSOs could be compared with each other and the original syllabus as a reliability measure. Rank-ordering the results and using the mean choices of each LSO pair enabled the generation of the accompanying list of variables in terms of difficulty for the LSO task.

Cautions for interpretation of the data are listed here:

a. the small sample size limits the scope of the generalizations.

b. the uneven exposure to HUD and CLASS systems makes the placement of these variables questionable.

c. frequently, the LSO pair disagreed on the most difficult variable in a given scenario.

d. upon post-task interview, it was found that not all LSOs thought of redundant information such as horizon condition as a possible variable for rating as most-difficult; this biases the results in favor of individual emergency difficulty.

e. the original list sequence was produced from the master syllabus; thus, placement of variables tended to follow the syllabus sequence and results are probably higher in concurrence than would be the case if a random pool were used. The extremely high correlations still provide encouraging support, however, that the original syllabus was fundamentally correct in its ordering. Additional support is found in the fact that the test lists were not mirror images of that syllabus, and LSOs were free to completely reorder the sequence as they saw fit.

SYLLABUS VARIABLES

Aircraft with no external lights
No horizon and no plane guard destroyer
Significant deck motion
Lens out of calibration
Moderate deck motion
Weak hook downspring or dashpot
Low fuel state aircraft on the ball
Missing wires
CLASS system inoperative
MOVLAS inoperative
Loss of engine on approach
CQ pilots on approach
Ziplip/Emcon recovery
No tanker and/or long divert
Ship running out of sea room
ACLS Mode I malfunction
Cut lights (pickle) inoperative
Deck runway lights inoperative
Two aircraft at the start position
Lens inoperative - LSO talkdown
Excessive criticism from Air Boss and/or CO
Pilot with vertigo
Ship in a turn
Pilot with a record of bad passes
No horizon but with plane guard destroyer
Low fuel state aircraft in the pattern
Significant crosswind (right to left)
Flap blowup on approach
HUD system inoperative
Use of MOVLAS for control
High wind over the deck
Deck out-of-trim
Flight control problems
Waveoff lights (pickle) inoperative
Aircraft breaks out inside 3/4 mile (bad weather)
Aircraft with taxi light on
Barricade recovery
LSO radios intermittent or inoperative
Deck drop lights inoperative
Hook-to-ramp indicator inoperative
PLAT inoperative
Hydraulic failure (any high approach-speed recovery)
Deck noise
Activity in landing area
Wind-over-the-deck indicator inaccurate
Slow-retracting wire, delayed clear deck
Bad CCA start
Intermittent LSO radio transmitter
Use of DLC
PAR inoperative
Horizon but no plane guard destroyer
Partial external lighting (aircraft)
Minimum wind-over-the-deck
Gross start deviations
Smoke in the groove
Aircraft goes NORDO on final
Lens setting indicator inoperative
APC system inoperative
Deck goes foul in close
Wind-over-the-deck indicator inoperative
Stuck AOA light
Foul deck after clear deck (in close)
CATCC fails to change LSO radio frequency
SPS 42 system inoperative
Aircraft known to be NORDO
Pilot loses ball during approach because of deviations
Incorrect aircraft configuration
SPS 44 system inoperative
Inoperative AOA light
Unusual pilot responses to control
Foul deck until aircraft is in close
ACLS Mode I approach
Pilot CLARA at start

Results:

Composite analysis comparing the LSO's rankings with the Original Syllabus Sequence.

Totals:

Correlation (r') = 0.8388
Student's T test (t) = 8.24
Probability of a random occurrence of a correlation the size of the one indicated above is less than .01 ($p < .01$)

Analysis by LIST:

LIST 1		LIST 2		LIST 3		LIST 4	
r' =	0.8376	r' =	0.8744	r' =	0.8566	r' =	0.7868
t =	8.0566	t =	9.5550	t =	8.7616	t =	6.5987
p <	0.01	p <	0.01	p <	0.01	p <	0.01

Analysis by LIST by Subject:

LIST 1	ORIGINAL-LSO1	LSO1-LSO2	ORIGINAL-LSO2
r' =	0.797	0.444	0.600
t =	5.111	1.919	2.905
p <	0.01	0.050	0.01
LIST 2			
r' =	0.848	0.522	0.662
t =	6.197	2.370	3.420
p <	0.01	0.025	0.01
LIST 3			
r' =	0.730	0.534	0.750
t =	4.137	2.446	4.392
p <	0.01	0.025	0.01
LIST 4			
r' =	0.750	0.665	0.652
t =	4.392	3.449	3.330
p <	0.01	0.01	0.01

APPENDIX G

LSO QUESTIONNAIRE RESULTS

This appendix contains a copy of the questionnaire which was distributed throughout the LSO community and a summary of questionnaire results.

QUESTIONNAIRE SUMMARY -- LSO COMMENTS and SUGGESTIONS

Qualities that separate the outstanding LSO

Overwhelming emphasis on cool behavior under stress, ability to see problems early or, preferably, before they happen. Having the confidence of peers was important and, of special note, were all the comments concerning instructional/debrief ability and ability to properly size up pilot problems. Jerry Arbiter (CVW-15) and Ted Whitehouse were the two named examples.

LSO's who dropped out of training

Main response was with frustration of students; it takes more motivation to put in the long hours, especially when their squadron mates are flying more and working less (which, according to the questionnaires was, in fact, the case). It also was seen as discouraging that so many started training, knowing that only a few would qualify by the end of training--i.e., why even try, with the limited chance of success? Finally, poor performance around the boat was seen as a factor, in that it destroyed the LSO's credibility with his peers.

LSO's who failed to qualify

With few exceptions, the reasons were poor perceptual ability or other factors, such as judgment of deviations, which resulted in the student progressing too slowly and either dropping out or being asked to quit.

LSO Phase I school

Comments in favor were all over the board. People who complimented one aspect were contradicted by others. In essence, the exposure to the new community was seen as a benefit, as well as the instruction of recovery equipment (which, it seemed, varied greatly in quality from class to class). The recovery equipment knowledge was beneficial in that it kept the LSO's image as an expert intact; i.e., they were able to stay one step ahead of their peers. No clear conclusions from this section, other than that the Phase I training has been inconsistent. Part of the inconsistency is due to the fact that some attended Phase I training before the establishment of the school.

Phase II and Phase III training

Mixed feelings whether Phase II should be lengthened or shortened and worked in to Phase III. Primary reactions were for more MOVLAS and for a higher proportion of time spent in a controlling capacity. These were followed by an emphasis on personal judgment on when a student is "ready"--any arbitrary block filling on phase completion was rejected. Coupled with this sentiment was a stand for standardization in training: some kind of comprehensive sequence or structure--to use as a basis for these phases, with a set of understandable and high standards for qualification. One LSO said that his RAG squadron had no Phase II as such, and several more made the comment that squadron quals are coming too easily--the RAG's are getting marginal LSO's from the fleet. It was recognized that a lot of these factors are influenced by fleet cruise schedules, but the dissatisfaction with present standards was clear. One suggested that all trainees follow the RAG CQ dets, even when assigned to their respective squadrons, as a way to get more experience.

HUD System

Some comments that its effectiveness was based on location, that the CLASS system should be incorporated, and that the UP time should be increased through design or maintenance training. Some specific recommedations: lens setting indicators should be moved to make them easier to read; improve the PLAT display; put fouled deck light closer to LSO field of vision; put radio controls on the HUD console; some other lineup indicator than PLAT, which could be put on a HUD combining glass; code lens settings by A/C type, not angle. Some of these comments are already being pursued in on-going discussions by the Navy concerning the future of HUD and CLASS.

Improved Displays

Better PLAT camera, in keeping with its importance to the waving task; hook touchdown point display, CRT display of aircraft side number, etc. which could be sent down from air ops; wireless radio headset; LEX has an air ops repeater that words well.

Visual cues

F-4 Engine sound in close
Night-triangle of lights
Nosewheel in vicinity of aux air doors
Plenty of black smoke

A-7 Nosewheel on UHT
Wing & appraoch lights form a straight line
Top of mainmounts aligned with UHT
Width of space between T/E flaps and top of UHT
Nosewheel above line between mainmounts
UHT halfway between T/E flap line and line between mainmounts
Nosegear is flush with fuselage for on-speed
Nosetires are flush with tailcone for on-speed beyond 1/8th mile

A-6 Horizontal stab just below wing
Tanks in relation to vertical stabilator
Horizontal stabilizer slightly below flaps
All lights should line up for on-speed
Nosegear in relation to main gear
Immediate glideslope change in response to power
Upper grimes light not visible

F-14 Nosewheel in line with lower lip of left intake
Approach light slightly above a line between wingtip lights
Nosewheel slightly below aft fuselage
Horizontal stab movement
Nosewheel in relation to intakes
Dim approach light if A/C coming right to left
LE of tail at top of stainless steel on main gear strut
Rudder does not control direction much, makes A/C fly sideways
Tops of tails just above wing root area

E-2 1/4 to 1/3 of vertical stab visible above wing
No popping sound (sound means rudders not in trim)
Fuselage alignment lights both visible
Aft attitude light on port side is attitude & rudder trim reference

A-3 Gap between horizontal stab and wing
Approach light slightly below wingtip lights
Engine sound
Keep left wingtip light closing on a point close to left foul line for lineup
Horizontal stab tips visible above wing root

A/TA-4 Bottom of nosewheel tangent with T/E of flaps
1/3 of nose tire visible below full flaps bottom edge

Comments and suggestions

Emphasized need for command support (some CO's don't feel they "need" LSO's in their outfits, load them down with other collateral duties).

Emphasized lack of fleetwide standardization in training, qualification, and evaluation.

Among training situations, suggested simulation of aircraft much further out than 3/4 mile, so LSO can take over a bad pass early; Enterprise burble; port list; demonstration of classic "crashes" and teach corrections that should have been made; show different decks and equipment layouts when an airwing gets married to a particular carrier.

Regarding training, some suggested less time for trainee spent keeping pass grades, more time spent looking at aircraft.

Most LSO's felt that the trainer, if properly built and used, would be a good training aid. Resistance falls in two categories:

1) The quantification of scoring or evaluation--everyone feels that the simulation is objective, but that evaluation can only be subjective
2) The money--if it came right down to it, they would rather see the trainer money spent on more mundane, but possibly more practical items, like platform radio maintenance/improved reliability of job aids.

No one liked the approach parameter section, either the way it was laid out, or the types of responses they were forced to give. Of those that answered this section, it should be noted that tolerances were frequently narrower on the low/slow side than in other dimensions; the numbers were not equal around the approach path.

SUMMARY OF LSO QUESTIONNAIRE DATA

1. <u>Autobiographical Data</u>

Sample N = 54
East Coast = 15
West Coast = 29
Training Cmd = 10
All aircraft communities sampled

Cruises - 2.25
Combat Cruises -1.43 (N=21)
CQ Dets - 8.73 (N=37)

In-Type Hours - 961
Day Traps - 215
Night Traps - 76

2. <u>Job/Training Data</u> (for Ranges, 1 = highest rating)

a.	LSO Assessment	(Range = 1-4)
	Aviation ability	1.60
	Reaction under stress	1.02
	Motivation	1.21
	Perceptual ability	1.20
	Aircraft knowledge	1.60
	Get along with others	1.78
	Officer-like qualities	2.55
	Instill confidence	1.20
	Instructional ability	1.63
	Recovery equipment	1.89
	Most Important	
	Stress reaction	25
	Perceptual ability	16
	Motivation	7
b.	Phase I School	(Range = 1-4)
	Aircraft performance	2.58
	Landing aids	1.87
	Recovery equipment	2.07
	Instruction technique	2.64
	Use of publications	2.42
c.	Phase II Training	(Range = 1-3)
	Day passes	1.86
	Night passes	1.65
	Aircraft variety	1.24
	Day control	1.53
	Night control	1.35
	MOVLAS	1.08
	Time in phase	1.78

d. Phase III Training (Range = 1-3)

Day passes	1.84
Night passes	1.76
Aircraft variety	1.71
Day control	1.49
Night control	1.22
MOVLAS	1.14
Time in phase	1.98

e. Workstation Displays (Range = 1-2)

	Control	Personnel
Day Recoveries:		
PLAT	1.80	1.76
SPN 12	2.01	1.68
SPN 10/42	1.96	1.71
HOOK TO RAMP	1.96	1.58
WIND OVER DECK	1.45	1.33
LENS SETTING	1.65	1.42
Night Recoveries:		
PLAT	1.48	1.73
SPN 12	2.00	1.77
SPN 10/42	1.92	1.63
HOOK TO RAMP	1.94	1.59
WIND OVER DECK	1.59	1.34
LENS SETTING	1.65	1.44

f. Workstation Displays - Training

Day Recoveries:	Control (R=1-4)	/Personnel (R=1-2)
PLAT	2.52	1.18
SPN 12	3.47	1.12
SPN 10/42	3.32	1.19
HOOK TO RAMP	2.75	1.27
WIND OVER DECK	1.49	1.57
LENS SETTING	1.62	1.44
Night Recoveries:		
PLAT	1.82	1.12
SPN 12	3.12	1.15
SPN 10/42	3.27	1.24
HOOK TO RAMP	2.83	1.21
WIND OVER DECK	1.50	1.53
LENS SETTING	1.62	1.40

g. Approach Parameters (N= approx 35)

(See next page)

DAY RECOVERIES:

	1/2 Mi			1/4 Mi			1/8 Mi			W/O Min		
	T	B	W	T	B	W	T	B	W	T	B	W
LINEUP (degrees)	1.74	4.34	3.21	1.29	2.68	2.04	1.16	1.74	1.53	1.01	1.44	1.33
GLIDESLOPE (feet)	12.79	36.46	29.68	6.41	17.37	14.97	3.69	8.46	6.76	2.19	5.40	4.57
AIRSPEED (knots)	4.09	6.00	6.31	2.90	4.97	4.78	1.51	4.03	3.62	2.79	3.34	3.23
ATTITUDE (degrecs)	2.95	4.72	4.01	2.09	3.64	3.02	1.56	2.82	2.54	1.38	2.33	2.33
WING MOVE (degrees)	3.47	--	--	2.91	--	--	2.11	--	--	1.84	--	--

NIGHT RECOVERIES:

	1/2 Mi			1/4 Mi			1/8 Mi			W/O Min		
	T	B	W	T	B	W	T	B	W	T	B	W
LINE UP (degrees)	1.93	3.24	3.29	1.47	2.65	2.22	1.39	1.64	1.96	1.06	1.50	1.34
GLIDESLOPE (feet)	14.02	31.71	28.15	7.35	15.24	17.64	4.29	8.10	7.64	2.18	5.07	4.53
AIRSPEED (knots)	4.52	6.18	6.08	3.88	4.67	4.45	2.62	3.88	3.48	2.04	3.59	3.43
ATTITUDE (degrees)	3.92	4.84	4.45	2.95	3.80	3.34	1.92	2.73	2.51	1.48	2.28	2.15
WING MODE (degrees)	4.26	--	--	3.10	--	--	2.33	--	--	2.00	--	--

DISTANCE TOLERANCE:

	1/2 Mi	1/4 Mi	1/8 Mi	W/O Min
DAY	388	211	99	49
NIGHT	533	294	147	65

WAVE OFF DISTANCE: 429 feet

h. Perceptual Cues

DAY RECOVERIES: (Range = 1-4)

	1/2 Mi	1/4 Mi	1/8 Mi	W/O Min
FUS LTS	3.76	3.76	3.84	3.86
APP LTS	2.78	2.65	2.50	2.33
ENG SMOKE	3.13	3.00	2.86	3.02
ENG PITCH	3.24	2.40	1.92	1.63
SHIP WAKE	3.08	3.21	3.32	3.49
HORIZON	2.21	2.33	2.61	2.92
DECK MOTION	1.64	1.76	1.25	1.04
CATCC	2.84	3.53	3.80	3.85
LSO CALLS	2.71	2.44	1.89	1.79
CONSOLE	2.00	2.81	3.10	3.21
ATT REF	1.68	1.49	1.36	1.34
ROLL REF	1.96	1.77	1.63	1.58

NIGHT RECOVERIES:

	1/2 Mi	1/4 Mi	1/8 Mi	W/O Min
FUS LTS	2.05	1.77	1.86	2.23
APP LTS	1.32	1.23	1.23	1.50
ENG SMOKE	4.00	4.00	4.00	4.00
ENG PITCH	3.05	2.41	1.68	1.18
SHIP WAKE	3.89	3.78	3.78	3.89
HORIZON	1.65	1.40	1.45	1.55
DECK MOTION	2.10	1.55	1.25	1.25
CATCC	1.80	3.00	3.75	3.75
LSO CALLS	2.40	2.20	1.60	1.80
CONSOLE	2.10	2.30	2.70	2.80
ATT REF	3.00	2.75	2.00	1.78
ROLL REF	2.78	2.56	2.00	2.00

i. Waving Strategies

POWER CHNG	-	1) Attitude (39)	2) Glideslope (15)
LINEUP CHNG	-	1) Power (38)	2) Attitude (13)
AIRSPEED CHNG	-	1) Power (35)	2) Attitude (31)
ATTITUDE CHNG	-	1) Power (40)	2) Airspeed (17)
GLIDESLOPE CHNG	-	1) Power (45)	2) Attitude (29)

AUTOBIOGRAPHICAL DATA

NAME ______________________ BIRTH DATE ____________

TELEPHONE WHERE YOU CAN BE REACHED ____________________

HIGHEST LEVEL OF EDUCATION

INSTITUTION	MAJOR	DEGREE	COMPLETION DATE
________	________	________	____________

COMMISSIONING DATE ________ SOURCE USNA ___ NAVCAD ___

AOCS ___ AVROC ___

ROTC ___

NUMBER OF CRUISES COMPLETED ______

NUMBER OF COMBAT CRUISES ______

NUMBER OF CQ DETS (RAG LSOs) ______

SHORE DUTY ASSIGNMENTS ____________________

____

____

DATE OF PILOT DESIGNATION ______________

FIRST AIRCRAFT (TYPE) ASSIGNMENT ___________

FLIGHT EXPERIENCE AFTER DESIGNATION

AIRCRAFT MODEL	APPROXIMATE HOURS	NATOPS CURRENT (yes/no)
______	________	___
______	________	___
______	________	___
______	________	___

(APPROXIMATE) CARRIER LANDINGS

DAY	NIGHT
______	______

LSO PHASE I SCHOOL COMPLETION DATE ____________

FIELD LSO QUALIFICATION DATE ____________

SQUADRON LSO QUALIFICATION DATE ____________

WING LSO QUALIFICATION DATE ____________

TRAINING LSO QUALIFICATION DATE ____________

STAFF LSO QUALIFICATION DATE ____________ page 2

ANY ADDITIONAL LSO QUALIFICATIONS/EXPERIENCE ____________________
____

WHAT TYPE AIRCRAFT WERE YOU FLYING WHEN YOU ENTERED LSO TRAINING?
____

WHAT TYPE AIRCRAFT WERE YOU FLYING WHEN YOU WERE QUALIFIED AS A SQUADRON LSO? _______

WHAT ARE YOUR CURRENT DUTIES AS AN LSO? ________________________
____

WHAT ARE YOUR CURRENT DUTIES AS A NAVAL AVIATOR? _______________
____

LSO EXPERIENCE

By aircraft model -- please check the aircraft you have waved, with the approximate degree of your experience

	slight	extensive		slight	extensive
F-4	____	____	A-4	____	____
F-8	____	____	A-6	____	____
F-14	____	____	A-7	____	____
C-1	____	____	A-3	____	____
C-2	____	____	A-5	____	____
EA-6	____	____	E-1	____	____
E-2	____	____	S-2	____	____
S-3	____	____	AV-8	____	____

By carrier class -- please check the deck types you have waved on

27 CHARLIE	____
FORRESTAL	____
MIDWAY	____
KITTY HAWK	____
ENTERPRISE	____
NIMITZ	____

LSO ASSESSMENT

We would like to find out your opinions regarding the criteria that make a successful LSO. Based on your experience with peers, instructors, trainees, and work station assistants, please rate the following items in terms of their importance. What qualities are important in good LSO performance?

	Very Important	Important	Slightly Important	Not Important
AVIATION ABILITY	( )	( )	( )	( )
REACTION UNDER STRESS	( )	( )	( )	( )
MOTIVATION	( )	( )	( )	( )
PERCEPTUAL ABILITY	( )	( )	( )	( )
KNOWLEDGE OF AIRCRAFT PERFORMANCE	( )	( )	( )	( )
ABILITY TO GET ALONG WITH OTHERS	( )	( )	( )	( )
OFFICER-LIKE QUALITIES	( )	( )	( )	( )
ABILITY TO INSTILL CONFIDENCE	( )	( )	( )	( )
POTENTIAL AS AN INSTRUCTOR	( )	( )	( )	( )
KNOWLEDGE OF RECOVERY EQUIPMENT	( )	( )	( )	( )
Other ____________	( )	( )	( )	( )
Other ____________	( )	( )	( )	( )
Other ____________	( )	( )	( )	( )

Which of the above criteria do you think is the most important?
______________________ Why? ______________________________
____
____

What qualities do you feel are important for separating the outstanding LSO from the proficient one? Did you know an unusually good LSO instructor or friend? What, in your opinion, were the qualities of that individual that made him outstanding? Please be as specific as possible. Continue on the back of this sheet if necessary.

Do you know any LSO trainees who dropped out of the qualification process? ____________ If "yes," please give your opinions as to the reasons that this happened.

Do you know any LSO trainees who failed to qualify as LSOs? _____ If "yes," please give your opinions as to the reasons that this happened.

LSO TRAINING

Phase I school -- The following subjects are components of the formal instruction given during LSO Phase I school. Please rate the effect of each, based on your recollections and subsequent experience, on your later performance as an LSO.

	Great Effect	Moderate Effect	Slight Effect	No Effect
AIRCRAFT PERFORMANCE	( )	( )	( )	( )
VISUAL LANDING AIDS	( )	( )	( )	( )
RECOVERY EQUIPMENT	( )	( )	( )	( )
INSTRUCTIONAL TECHNIQUES	( )	( )	( )	( )
USE OF PUBLICATIONS	( )	( )	( )	( )

What would you say were the main benefits of LSO Phase I school?

What do you think were the least helpful/useful elements of LSO Phase I school?

What suggestions would you make for improving the formal classroom training at Phase I school?

Phase II (FCLP) -- The following section contains some possible changes that could be made in the FCLP phase of LSO training. Please mark your opinion in each case. Should that portion of training be increased, decreased, or should it stay the same. If you have no opinion, please mark the column "STAY THE SAME."

	INCREASE	STAY THE SAME	DECREASE
Number of Day passes observed	( )	( )	( )
Number of NIGHT passes observed	( )	( )	( )
Variety of aircraft observed by trainee	( )	( )	( )
Number of DAY passes in controlling capacity	( )	( )	( )
Number of NIGHT passes in controlling capacity	( )	( )	( )
Amount of time using MOVLAS	( )	( )	( )
Amount of time in this phase before going to carrier	( )	( )	( )
Other ______ ______	( )	( )	( )
Other ______ ______	( )	( )	( )

What other suggestions would you make for improving Phase II training?

Phase III (Carrier) -- The following section is similar to the one you have just completed, with this qualification: you should consider the standards necessary to qualify an LSO trainee at the squadron level (i.e., to wave a single type of aircraft during both day and night operations), when considering the training times listed below.

	INCREASE	STAY THE SAME	DECREASE
Number of DAY passes observed	( )	( )	( )
Number of NIGHT passes observed	( )	( )	( )
Variety of aircraft observed by trainee	( )	( )	( )
Number of DAY passes in controlling capacity	( )	( )	( )
Number of NIGHT passes in controlling capacity	( )	( )	( )
Amount of time using MOVLAS	( )	( )	( )
Amount of time as workstation (PLAT, etc.) monitor	( )	( )	( )
Other ____________ ____________	( )	( )	( )
Other ____________ ____________	( )	( )	( )

What other suggestions would you make for improving Phase III training, in order to initially qualify a Squadron LSO?

WORKSTATION DISPLAYS

We would like to obtain information about your use of the LSO workstation displays. The devices found on the LSO console are listed below. Please check whether you use a given display as a "Control" device or as a "Monitor" device. That is, if the primary use of a display is for the actual control of an aircraft on approach, check the first column; if, however, the display is primarily used to update or monitor the overall recovery situation, then check the second column. Finally, please check whether the information from a given display is gathered by your personal monitoring efforts or whether the information comes primarily through the efforts of an assistant LSO, passing the information to you.

DAY RECOVERIES

	CONTROL	MONITOR	YOU	ASSISTANT
PLAT	( )	( )	( )	( )
SPN 12	( )	( )	( )	( )
SPN 10/42	( )	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )	( )

NIGHT RECOVERIES

	CONTROL	MONITOR	YOU	ASSISTANT
PLAT	( )	( )	( )	( )
SPN 12	( )	( )	( )	( )
SPN 10/42	( )	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )	( )

Workstation and training -- Assume for this section that you are supervising an LSO trainee at the platform (aboard ship); he has the "pickle" while you are handling the workstation displays. We would like to find out exactly which displays you consider to be most important to the trainee. How vital are certain kinds of console information to an individual who is trying to become Squadron LSO qualified? Please mark your judgments, using the checklist below. The two columns labeled "YOU" and "TRAINEE" are used to find out whether you would monitor that display for the trainee and pass the information to him, or whether you would prefer the individual to monitor the display for himself.

DAY RECOVERIES

	Very Important	Important	Slightly Important	Not Important	You	Trnee
PLAT	( )	( )	( )	( )	( )	( )
SPN 12	( )	( )	( )	( )	( )	( )
SPN 10/42	( )	( )	( )	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )	( )	( )	( )

NIGHT RECOVERIES

	Very Important	Important	Slightly Important	Not Important	You	Trnee
PLAT	( )	( )	( )	( )	( )	( )
SPN 12	( )	( )	( )	( )	( )	( )
SPN 10/42	( )	( )	( )	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )	( )	( )	( )

HUD workstation -- If you have used the new HUD console arrangement, please complete this section. If you have not, just proceed to the next section.

We would like to find out how the HUD console arrangement has changed your opinions of the individual devices and the time that you spend monitoring their information. In comparison to the standard LSO workstation, please mark below whether or not each device or indication is easier to monitor with the HUD.

	Easier	No Difference	Harder
PLAT	( )	( )	( )
CLOSURE RATE INDICATIONS	( )	( )	( )
OTHER SPN 42 INDICATIONS	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )

Please indicate below whether you monitor each device or indication on the HUD console more or less than that same device on a standard workstation.

	More	The Same	Less
PLAT	( )	( )	( )
CLOSURE RATE INDICATIONS	( )	( )	( )
OTHER SPN 42 INDICATIONS	( )	( )	( )
HOOK TO RAMP INDICATOR	( )	( )	( )
WIND OVER DECK INDICATORS	( )	( )	( )
LENS SETTING INDICATORS	( )	( )	( )

In general, do you like to use the HUD more than the standard workstation?

YES ______ NO ______

Would you rather use the HUD console to train new LSOs or introduce them to the standard workstation first?

HUD __________ STANDARD __________

What changes would you like to see in the HUD console?

Do you have any ideas regarding new displays that you would like to see added to the workstation console to assist the recovery process? If so, what are they?

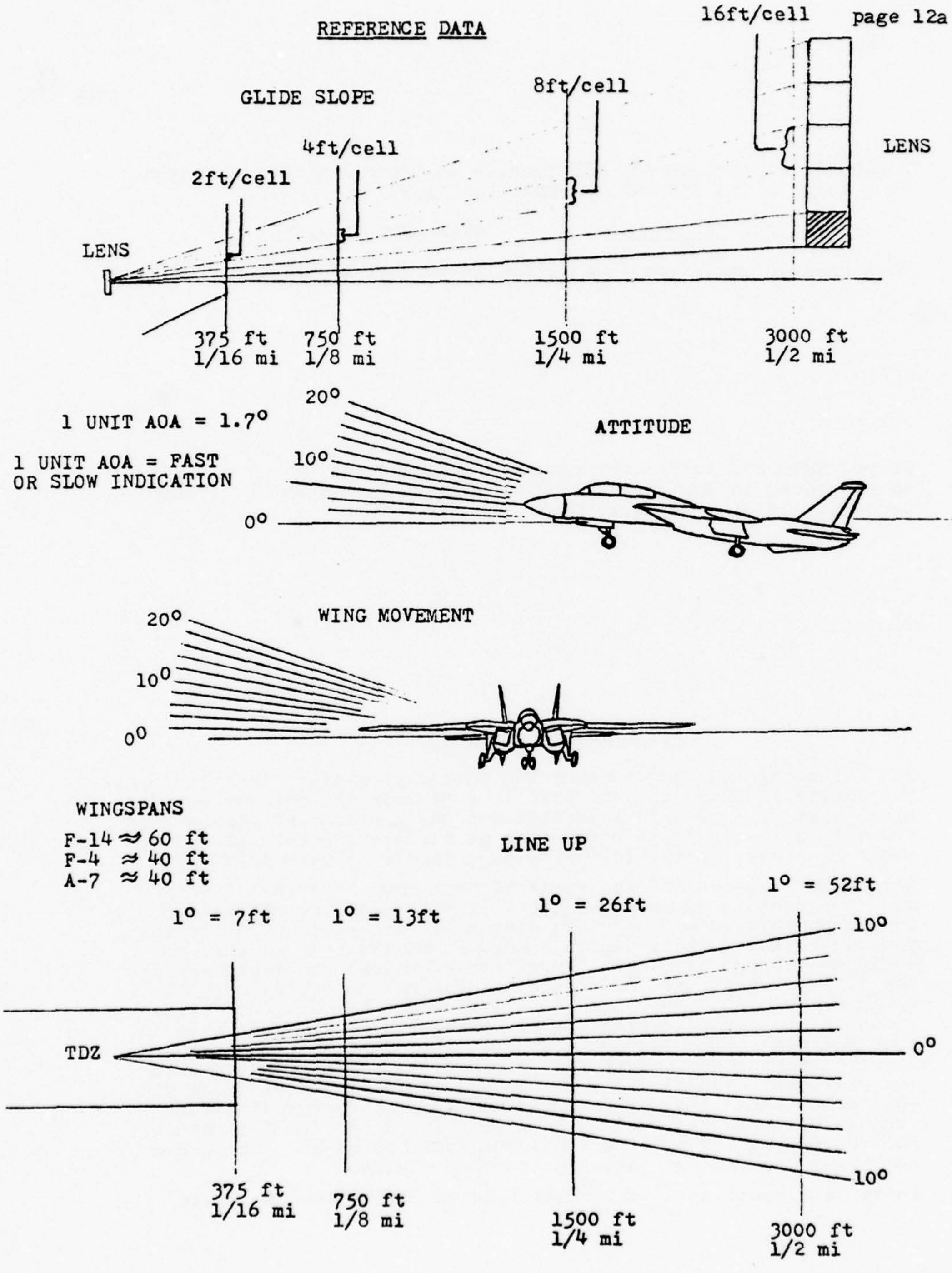
APPROACH PARAMETERS

The following section concerns the flight parameters that you monitor during an approach. We would like to know the minimum deviations that you are able to detect and the maximum deviations that you will allow in these parameters at different points along the pass. The chart on the following page should be used this way:

The column labeled "T" has space to mark your "threshold" values or, the absolute minimum changes that you think you can detect in the parameters at the given distance. For example, do you think you can detect a three-degree change in attitude at ½ mile, or would the change have to be four-degrees before you could see it? The "B" column is used to record the maximum deviation, from an optimum approach, that you will allow under the "best" of situations (e.g., a good carrier pilot coming aboard a steady deck in good weather). How far would you let a parameter be stretched in these circumstances before you took some corrective action from the platform? Finally, the "W" column is for the deviations you will allow under the worst conditions (e.g., a marginal pilot coming aboard in bad weather to a pitching deck, low fuel state). We are looking for your personal judgments as an LSO; there are no "right" or "wrong" responses to this section.

There is a section in this chart labeled "DISTANCE." We would

REFERENCE DATA



like to know how accurately you think you can judge the distances in the chart. For example, when you decide that an aircraft on approach is at ½ mile, how much error do you think is in your estimate? This is the response we want under each column. All distances are given from the touchdown point except "W/O MIN;" this is your subjective minimum, the distance at which you believe that a landing commitment must be made. This may vary between LSOs, but in all cases it will indicate the closest point at which each LSO feels he can work an aircraft. If the question is made more meaningful by designating an aircraft type, please evaluate only the aircraft you are most qualified to wave.

(PLEASE USE THE REFERENCE DATA ON THE NEXT PAGE)

DAY RECOVERIES

	1/2 MI			1/4 MI			1/8 MI			W/O MIN		
	T	B	W	T	B	W	T	B	W	T	B	W
LINE UP												
GLIDE SLOPE												
AIRSPEED												
ATTITUDE												
WING MOVEMENT												
DISTANCE	±			±			±			±		

NIGHT RECOVERIES

	1/2 MI			1/4 MI			1/8 MI			W/O MIN		
	T	B	W	T	B	W	T	B	W	T	B	W
LINE UP												
GLIDE SLOPE												
AIRSPEED												
ATTITUDE												
WING MOVEMENT												
DISTANCE	±			±			±			±		

What is your foul deck waveoff distance, for your model aircraft, assuming all other aspects of the approach are normal? __________ FT.

PERCEPTUAL CUES

We would like to find out exactly how important certain cues are in the waving process. Furthermore, we would like to gather this information for selected points on the approach. Please indicate the importance you attach to each cue below at the distances listed. Make your choices only for the aircraft type that you are most qualified to wave. Space is provided for cues which we have failed to list and which you feel are useful to you.

Aircraft that you are using for this checklist ________________

NIGHT RECOVERIES

1 Very Important — 2 Important — 3 Slightly Important — 4 Not Important

	1/2 MI 1 2 3 4	1/4 MI 1 2 3 4	1/8 MI 1 2 3 4	W/O MIN 1 2 3 4
FUSELAGE LIGHTS	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
APPROACH LIGHTS	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
ENGINE SMOKE	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
ENGINE PITCH	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
SHIP WAKE	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
HORIZON	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
DECK MOTION	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
CATCC CALLS	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
ASST LSO CALLS	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
CONSOLE DISPLAYS	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
FUSELAGE REFERENCES FOR ATTITUDE	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
FUSELAGE REFERENCES FOR ROLL & DIRECTION	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
__________	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
__________	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )
__________	( )( )( )( )	( )( )( )( )	( )( )( )( )	( )( )( )( )

PERCEPTUAL CUES

We would like to find out exactly how important certain cues are in the waving process. Furthermore, we would like to gather this information for selected points on the approach. Please indicate the importance you attach to each cue below at the distances listed. Make your choices only for the aircraft type that you are most qualified to wave. Space is provided for cues which we have failed to list and which you feel are useful to you.

Aircraft that you are using for this checklist ________________

DAY RECOVERIES

1	2	3	4
Very Important	Important	Slightly Important	Not Important

	1/2 MI				1/4 MI				1/8 MI				W/O MIN			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
FUSELAGE LIGHTS	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
APPROACH LIGHTS	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
ENGINE SMOKE	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
ENGINE PITCH	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
SHIP WAKE	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
HORIZON	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
DECK MOTION	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
CATCC CALLS	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
ASST LSO CALLS	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
CONSOLE DISPLAYS	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
FUSELAGE REFERENCES FOR ATTITUDE	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
FUSELAGE REFERENCES FOR ROLL & DIRECTION	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
________	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
________	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )
________	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )	( )

What specific visual cues do you use for your particular aircraft? Please list as many of the "gouge" points for your model of aircraft as you can think of; when that aircraft looks "right" to you on approach. Do you line up the nosewheel with the aux air doors? Tip of the horizontal stabilizer just visible above the wing root?

CUE STRATEGIES

We would like to find out about how LSOs combine individual cues into strategies of waving aircraft. So far, we have only considered each cue as a separate and distinct item; to provide some information about how to arrange them into a logical pattern, we would like you to complete the next section on performance parameters.

This section contains a series of checklist-response type items. Starting from a normal pass, within safe limits all the way, consider that you see the change given on the left side of each item. Please check which of the possible responses you would look for from the pilot to keep the aircraft within safe limits.

More than one choice may be possible, but not every one is relevant to the immediate task of keeping the aircraft within limits for a safe approach. For instance, a power increase may be followed by an increase in airspeed, but the object of this section is to judge what the pilot would do to keep the aircraft on the approach so, for whatever reason the power was increased, the best choice for the next event would be an attitude change to compensate for it. Notice that there are no provisions for the simple case of an event reversal. Therefore, a power increase cannot be paired with a power decrease -- that would be too simple, and we are interested in the relationships between different parameters.

Space is provided within each item for an event that you would look for from a pilot, but that we have failed to list. Please consider only the aircraft that you are most qualified to wave, the same one that you considered in the LSO CUES section.

POWER CHANGE	_____	LINE UP CORRECTION
	_____	ATTITUDE CHANGE
	_____	AIRSPEED CHANGE
	_____	GLIDESLOPE CHANGE
	_____	_______________
LINE UP CORRECTION	_____	ATTITUDE CHANGE
	_____	GLIDESLOPE CHANGE
	_____	AIRSPEED CHANGE
	_____	POWER CHANGE
	_____	_______________
AIRSPEED CHANGE	_____	GLIDESLOPE CHANGE
	_____	ATTITUDE CHANGE
	_____	POWER CHANGE
	_____	LINE UP CORRECTION
	_____	_______________
ATTITUDE CHANGE	_____	POWER CHANGE
	_____	LINE UP CORRECTION
	_____	AIRSPEED CHANGE
	_____	GLIDESLOPE CHANGE
	_____	_______________
GLIDESLOPE CHANGE	_____	AIRSPEED CHANGE
	_____	POWER CHANGE
	_____	LINE UP CORRECTION
	_____	ATTITUDE CHANGE
	_____	_______________

REMARKS

This is your opportunity to offer your comments concerning this survey form or the simulator project. Would you have changed, deleted, or added to any of the items included in this form?

APPENDIX H

VISUAL SIMULATION DATA

This appendix provides detailed information on visual system technology as well as human visual perception. It is broken down into four sections:

Section 1 Human Visual Perception

Section 2 Image Generation

Section 3 Image Display

Section 4 Visual Simulation Industry Overview

SECTION 1

HUMAN VISUAL PERCEPTION

In order to establish the requirements for any training system using visual cues, it is necessary first to understand human visual capabilities. Total evaluation of human visual perception is very complex and goes beyond the scope of this report. Its most significant aspects, however, are detailed in the following paragraphs. One reference document proved to be a good source of information on visual perception and its relationship to visual systems considerations (Farrell and Booth, Dec. 1975).[1]

1.1 HUMAN VISUAL ACUITY

Acuity is a measurement of the ability to discriminate objects in a scene. Four of the major types of measurement follow: See Figure H-1.

- Minimum Separable Acuity — Minimum separable acuity (resolution) is the ability to differentiate a gap between two closely spaced objects. For example, if an observer, viewing the night sky, is able to discern two stars which appear to be almost merged as one, he is *demonstrating* his own minimum separable acuity. Under these conditions the average viewer will be able to discriminate the fact that he is observing two stars if those stars are separated by 40 seconds of arc (Keesey, 1960)[2] to one minute of arc (Helmholtz, 1866)[3] 50% of the time. It is important to note that when the observed object is an intense light source against a dark background, physical size does not define detectability. In this example, the size of the stars may be infinitely small as long as their level of intensity is great enough to be perceived.

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1 Farrell, Richard J. and Booth, John M., Design Handbook for Imagery Interpretation Equipment, D180-19063-1 (Seattle, Wash.: Boeing Aerospace Co., December, 1975).

2 Keesey, U.T. Effects of involuntary eye movements on visual acuity. Journal of the Optical Society of America, 1960, 50, 769-74.

3 Helmholtz, H. von. Handbuch der physiologischen Optik. Vol. 2. Hamburg & Leipzig: Voss, 1866. (Translation of 3rd ed. by J.P.C. Southall, Helmholtz's Physiological optics, Vol 2. Rochester, N.Y.: Optical Society of America, 1924.)

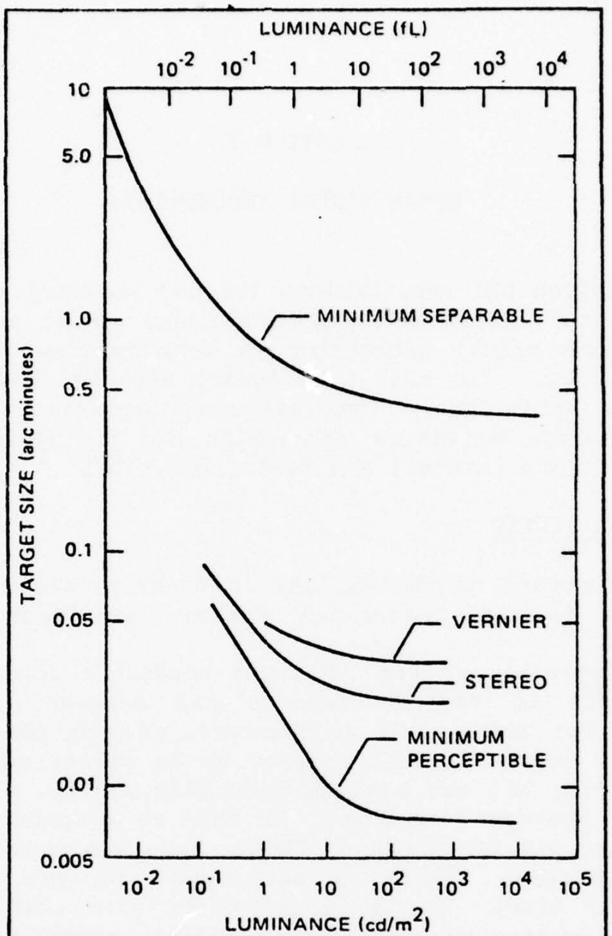

Figure H-1. Effect of Luminance on Acuity ("Adapted from Farrell and Booth")[4]

- Minimum Perceptible Acuity — Minimum perceptible acuity (detection) is the ability to detect the presence of a dark object against a light background. Two factors determine detectability. One is level of illumination and the second is the contrast between the object and the background. Given sufficient illumination and contrast, the average observer can detect a thin black cable against a bright sky if the cable is 0.25 inches wide at a distance of one mile away, 50% of the time. This dark line detection capability corresponds to 0.5 seconds of arc (Hecht and Mintz, 1939).[5]

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4 See footnote 1, p. 181.

5 Hecht, S., & Mintz, E.U. The visibility of single lines at various illuminations and the retinal basis of visual resolution. Journal of General Physiology, 1939, 22, 593-612.

- Minimum Vernier Acuity — Minimum vernier acuity (lateral) is the ability to perceive sideways displacement. If two identical objects are placed one above the other and one of the objects, say the lower one, remains fixed in place while the upper object is moved laterally to one side, the minimum displacement which can be made before detection of displacement occurs is approximately 2 seconds of arc. Vernier acuity is also known as lateral acuity. It is important to note that the objects are of identical size and equal distance from the viewer at the beginning of the test.

- Minimum Stereo Acuity — Stereo acuity can best be defined as an observer's ability to determine that one of two identical objects is closer to him than the other. In testing stereo acuity the observer views two identical rods, one placed above the other. The lower rod remains fixed as the upper rod is moved towards the observer. For the average viewer, when the two rods are noticeably different distances from each other, they are separated by 2 seconds of arc (Berry, 1948).[6] Other terms which are equivalent to stereo acuity are stereoscopic acuity, stereopsis, and depth perception. Here the fact must be recognized that these differences in depth which are perceived by the use of binocular vision are being demonstrated with two identical objects which are placed very close together, thereby causing direct comparisons to be made. To our knowledge no studies are available which show stereo acuity for a single object which is moving towards the viewer. The ability to judge relative depth does decrease dramatically as the reference object is moved laterally away from the test object. An object at a distance without a reference object may provide very little stereo derived depth information.

1.2 GENERAL NOTES

20-20 vision is defined as the human eye's capability of identifying alphabetic lettering which subtends a visual angle of at least 5 arc minutes. All types of visual acuity decrease in accuracy as the observed objects change from static to dynamic. All the preceding test data was taken from static targets. Many things affect visual acuity, in a negative way, and reduce these ideal findings. The following is a general list:

- Reduction in luminance
- Reduction in contrast
- Reduction in time available to look at or search for the target
- Introduction of a non-uniform background

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6 Berry, R.N. Quantitative relations among vernier, real depth, and stereoscopic depth acuities. Journal of Experimental Psychology, 1948, 38, 708-21.

- Introduction of noise
- Lack of experience with the viewing situation
- Lack of knowledge about the target shape and orientation
- Reduction in information about when a target will appear
- Displacement of the target from the fixation point
- Reduction in information about target location
- Reduction of the rate at which the targets appear
- Reduction in the reward for correct response relative to the penalty for reporting the wrong object, as a target
- Target motion

1.3 THE MEASUREMENT OF LIGHT

Because of the significance of the light intensity in target recognition it is important to have a basic understanding of its measurement. There are two concepts involved here. The first is Illumination or Illuminance. The second is Luminance. See Figure H-2.

- Illuminance. Illuminance is a measurement of the light striking the surface of an object. One common unit of measure for illuminance is the Foot Candle. By definition, a point light source of one standard candle placed inside a sphere with a radius of one foot creates an illuminance of one foot candle on the inner surface of this sphere. The new term for candle is Candela and is used to differentiate the newer international standard unit of measure.

- Luminous flux. See Figure H-3. The rate at which light energy passes through or strikes a given area is measured in a unit called a "lumen." The brightness with which a light source shines in a given direction (called luminous intensity) is measured in units called "Candelas." The two units are related as follows. A small uniformly radiating light source of one Candela gives a light flux of one lumen on (or through) a surface area of one square meter at distance one meter from the source.

  As the lumen is a measure of luminous flux, a smaller area closer to the source, but covering exactly the same solid angle would also receive a total luminous flux of one lumen. The same area at larger distance, or a smaller area at the same distance receives less than 1 lumen of luminous flux.

- Luminance. Luminance is the amount of light per unit area reflected from or emitted by a surface. This measurement is often confused with brightness. Brightness, however is a subjective judgment

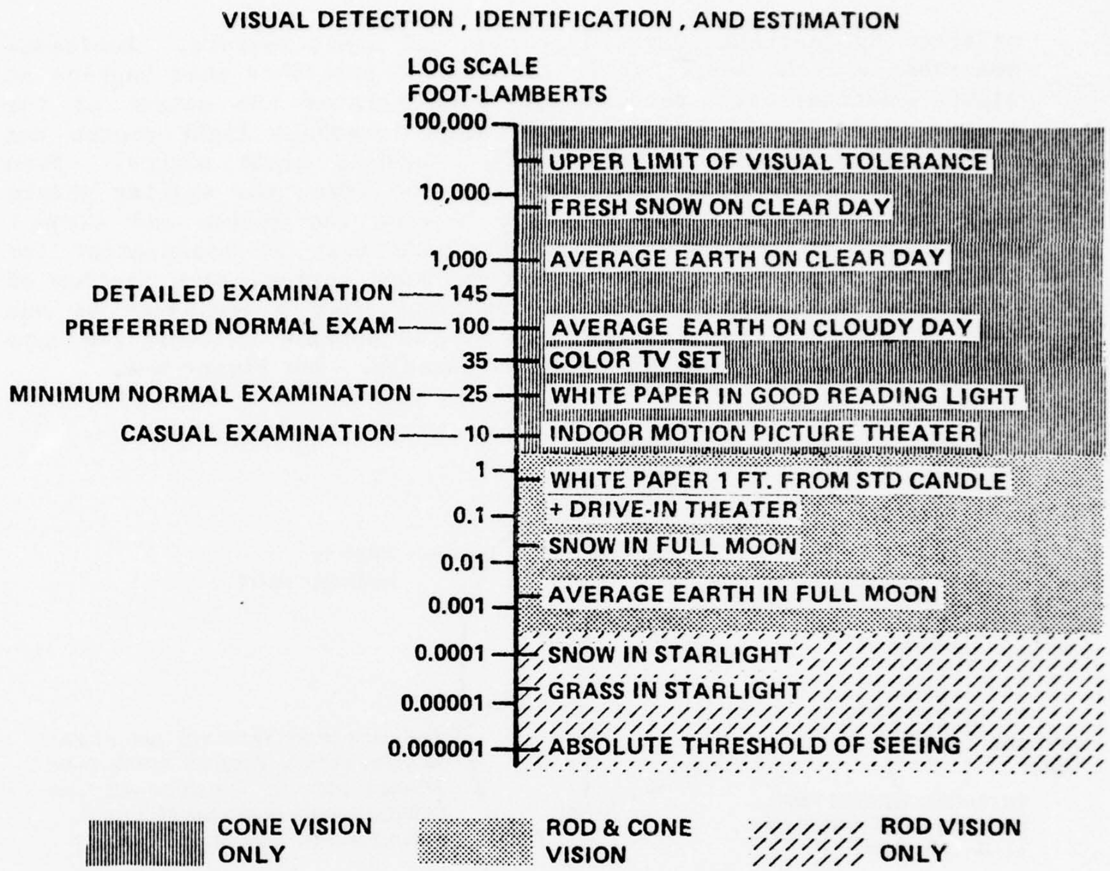

Figure H-2. Examples of Various Levels of Luminance ("Adapted from Human Engineering Guide to Equipment Design")[7]

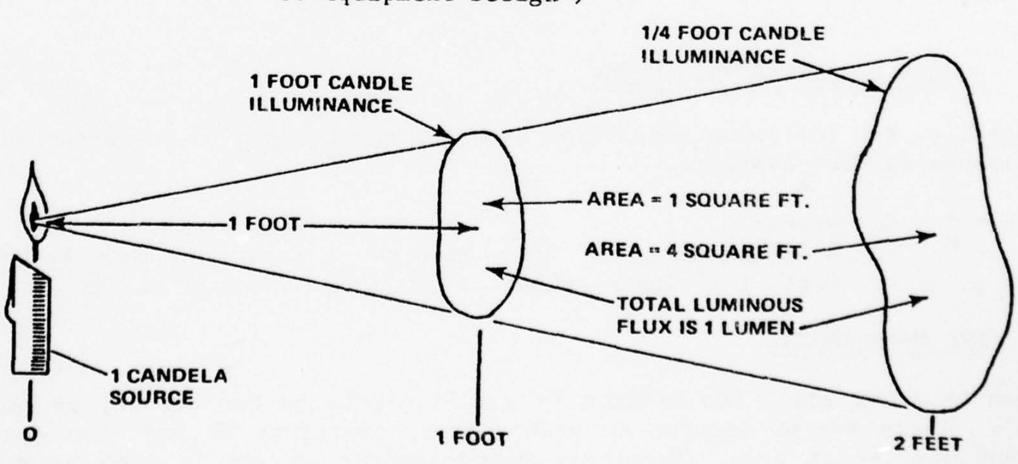

Figure H-3. Example of Luminous

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[7] Van Cott, H.P. and Kinkade, R.G., eds., Human Engineering Guide to Equipment Design (Washington: American Institutes for Research, 1972).

affected by contrast, dark adaptation and other factors. Luminance describes a light source while Illuminance describes what happens at lights destination. Because luminance relates the output of the source to its total area, a very large 1-candela light source has lower luminance than a very small 1-candela light source. Even though the total light output remains the same, the smaller source will look brighter. The distance between the source and subject illuminated is irrelevant. One standard unit of measurement for Luminance is the Foot-Lambert. An extended source, each portion of which radiates equally in all directions, has a luminance of one Foot-Lambert when each square inch of its surface radiates the same amount of light as a source of 1/144 candela. See Figure H-4.

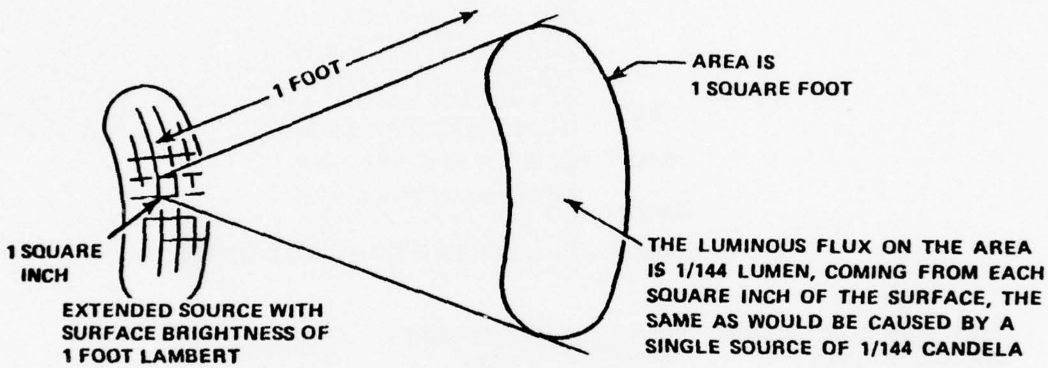

Figure H-4.

1.4 SCREEN LUMINANCE VS. LUMENS

Generally, the following simplified equation may be used to determine screen luminance in Foot-Lamberts.

$B = \frac{L}{A} \times G$ where:

B is luminance in Foot-Lamberts, A is screen area in square feet, L is lumen output of projector and G is screen gain.

1.5 ARC MEASUREMENT

If an observer scans the horizon in a full circle he has covered an arc of 360°. There are 60 minutes in each degree, therefore he has also covered 21,600 minutes of arc. There are sixty seconds of arc in each minute of arc. Consequently, he has also covered 1,296,000 seconds of arc. In measuring human visual perception, degrees, minutes, and seconds of arc are used as the basic units of measure. These units, when stated, simply given the angle subtended by the object being observed, or the angle subtended between two objects.

1.6 TYPICAL TARGET SIZES

We will choose an aircraft as a typical target and evaluate its size in degrees of arc at different distances. Our typical aircraft has a wing span of 40 feet and a lower wing surface visibility, in approach attitude, approximates five feet. At two miles, it is 0° 13' 01" of arc from wing tip to wing tip. At 1-1/2 miles it is 0° 17' 22" of arc from wing tip to wing tip. At 1 mile it is 0° 26' 2" of arc from wing tip to wing tip. At 2 miles with a nominal wing visibility of five feet, the wing appears 0° 1' 38" of arc thick. At 1-1/2 miles the wing appears 0° 2' 10" of arc thick. At 1 mile the wing appears 0° 3' 15" of arc thick.

1.7 FIELD OF VIEW (FOV)

Field of View is the angle measured in degrees, minutes, and seconds of arc which an observer can perceive when he looks at a particular visual scene. If an observer can see the entire horizon by turning in a full circle, he is said to have a 360° horizontal FOV. If he scans vertically starting with the horizon at the bottom of the scene and stopping his scan at the zenith directly overhead, he is said to have a 90° vertical FOV.

SECTION 2

IMAGE GENERATION

This portion of a visual system provides the visual information to be displayed. All relevant techniques are described.

2.1 CAMERA MODEL SYSTEM

Camera model systems have long been used as the source for visual information in simulation. An optical probe which represents the position of the observer is used to pick up the optical information from the model for processing by a Closed Circuit Television System (CCTV). In order that realistic velocity and distance cues are generated, the probe travels in a path and at a velocity scaled to the model. The advantage of camera model systems is that they provide a realistic approximation of the real world. There are some disadvantages such as:

a. The model itself which is not easily changed to allow for various scenes or objects to be portrayed.

b. There is a depth of focus phenomenon which manifests itself when the probe comes very close to the object being observed. Unless corrected, not all parts of the object will appear in sharp focus.

c. Though an object may be very detailed it does not have real world detail. Therefore, when the object is at a distance it appears to be quite realistic but on closer approach there is no additional resolution of detail provided and consequently no additional cues.

d. The optical probe, T.V. bandwidth and reasonable model size seriously limit resolution.

e. Mechanical devices are subject to mechanical inaccuracies, lags, overshoots, and backlash.

f. Because the area modeled is finite the gaming area is restricted. This, however, would not be a significant disadvantage in an LSO trainer.

g. The visual information that a model provides a student is relatively fixed and can only be changed in real time by adding additional hardware down stream in the CCTV system. The potential to change the visual cues in real time would allow the addition of synthetic visual cues to facilitate adaptive training.

2.2 PHOTOGRAPHIC SYSTEMS

Film is being used and has been used successfully in limited applications in the past. It allows for a scene, such as an approach to a landing, to be filmed and used in training. The film itself may be of an ideal approach. When used in conjuction with a simulator, the view is distorted optically to provide the student with the runway geometry he would see while making his own approach. For instance, if he is low the perspective of the scene is transformed optically so that the runway appears foreshortened. The advantage of film is image detail. However, the application of film technology to an LSO training system would be severely limited. Most importantly, optical transformation could not reveal previously hidden aircraft surfaces.

2.3 EARTH/SKY PROJECTOR

Some dome visual systems have used this method of generation and projection to provide a full sphere background scene. It is presented here although it fits in both image generation and display. In its static state, this type of generation/projection displays a sky scene in the upper hemisphere and an earth- or sea-scape in the lower hemisphere. The content of this scene does not change in real time but the scene position does change in response to the observer's changing attitude. The image generation/projection device is mounted on gimbals and can most easily be pictured if one imagines a point light source with a top hemisphere and a bottom hemisphere, made of clear glass or plexiglass, surrounding it. The sky scene and the earth scene are painted on the hemisphere. This background scene is used as a means to provide attitude information to the observer. Superimposed over it by means of projection is a target scene from a different type of projector. The target scene usually contains the changing visual information required to facilitate whatever type of training is taking place. One drawback in this type of system occurs because the target scene is projected over the background scene, the target itself appears somewhat transparent, and the background scene is visible through the target. Earth/sky projection cannot change visual cues such as weather or depict both day and night. The ideal position for this type of projector would be at the center of the spherical screen. It is impractical to position the projector in the center however, as this is also the best position for the observer. It is also impractical to use a single point light source to illuminate both the earth and the sky hemispherical portions of this projector; consequently, a single light source is used for each. This light source is positioned inside the projector at a point which bears the same relative position as that of the projector itself in relationship to the dome screen. This is done to correct the distortion which occurs when the projector is displaced from the center of the screen and the observer positioned there.

This technology may not be applicable to an LSO trainer because the background scene requires both moving and stationary cues (horizon vs. deck).

2.4 HOLOGRAPHIC VISUAL SYSTEMS

Holography, as here described, is an image storage media. Advances have been made in holography to the point where holographic motion pictures are practical today. Some experiments have been done to evaluate the potential for using holography to replace model board technology as an image storage media in trainers. However, as yet no practical method has come to light that would allow holography to be used in a real-time interactive visual system. Additional gains will have to be made before holography can be considered.

2.5 COMPUTER GENERATED IMAGERY (CGI)

- CGI Overview — CGI, also known as Computer Image Generation (CIG), is a relatively new and rapidly developing technology which appears to be the wave of the future. It must be acknowledged that no visual system can provide a training situation with the complexity of cues found in the real world. Nor is this necessary for transfer of training to take place. CGI continues to become more realistic and the limit is not yet in view. The complexity of the visual scene necessary to provide the requisite cues for training a pilot to make an approach to a landing are not necessarily those needed for training an LSO to observe the aircraft on that approach. It appears that the state-of-the-art in Computer Generation of Imagery is sufficient to allow for the generation of an adequately realistic aircraft to accomplish this task. At present, film and camera model systems provide more realistic day scenes but because of its flexibility, CGI allows the addition or deletion of visual cues to an extent not previously feasible with any other image generation technology. Artificialities may be added to aid the student in picking up the visual cues. Studies may be made to determine the effectiveness and cue priority structure of a given scene. This information may then be used to increase the complexity of scenes as the student progresses. Adaptive training may be facilitated to a much greater extent through the use of CGI than with a camera model system or a film image generation system. CGI can provide greater detail in the area of interest and less in the background scene. Because CGI lacks any mechanical components it is not subject to the failings of mechanically based systems such as excessive slop in tolerance, mechanical backlash, etc. In a replay mode, rapid scene changes could be accomplished to allow for a view from both the LSO's point of view or perhaps from any other point in space which might enhance training. In short, flexibility and growth capability are inherent to a CGI based image generation system. Its disadvantage is caused by the digital method in which scenes are assembled for display. The problems come under the title of "scene anomalies" or "aliasing."

- GCI Techniques — CGI is accomplished through the generation of a data base which defines a real world object or location. The data base domain is defined in terms of x, y, and z coordinates, thereby providing information for a three dimensional (3D) representation to be generated. The difference between a 3D representation and stereo or binocular vision must be recognized. A 3D representation provides perspective information in two dimensions with depth being implied. CGI systems use edges and points to define surfaces. By definition, four edges or points delineate a surface. Real world objects are depicted through the use of simple geometric forms such as triangles and polygons. These are combined into complex shapes as required. Current CGI technology is developing techniques for generating ovals and circles as well as surface texture. Texture will be used to delineate the ship's wake, in the LSO trainer as well as sea state. Hidden surfaces will show through solid objects unless Occultation is employed. This technique calculates which surfaces in a scene would be out of view and suppresses them. Curved surfaces are depicted by joining numerous flat surfaces. Smooth shading is used to give the appearance of an even curved surface. System capabilities are defined by the number of points of light or edges which can be generated. Restrictions may also be placed on the number of edge crossings in a raster scan system or the number of surfaces which may be depicted at any one time. These numbers can be well under the total capability of the system. For instance, an 8,000 edge system might be able to display only 2,000 edges at any one time. Depth cues, such as aerial perspective (haze causing distant objects to lose their color and appear gray towards the horizon), are generated. Color information exists as part of the data base as well. Various CGI techniques have been and are being developed to correct "scene anomalies" which are associated with raster scan displays. Some of these anomalies are described in Section 3 under raster scan.

SECTION 3

IMAGE DISPLAY

The image display portion of a visual system is the hardware which presents the scene to the viewer. Four major types of image display systems are discussed here. They are:

1. Cathode Ray Tube (CRT) (3.1)
2. Television Projection (3.2)
3. Hybrid (3.3)
4. Laser Projection (3.4)

Laser systems, as described, fit in both the Image Generation and Image Display area. They are presented here in the Image Display area because that is the portion of the system which can be considered most applicable to an LSO trainer.

3.1 CRT DISPLAYS, DIRECT VIEW

The term "direct view" is used here to imply viewing the CRT surface rather than a projected image. There are two types of CRT's which are of interest, Beam Penetration and Raster Scan. Direct view displays are often used in conjunction with an optical system which causes the image they produce to appear to be at infinity.

3.1.1 Beam Penetration CRT's

This technology is used extensively in night and dusk display applications. Calligraphic is another term which is used synonymously with this technology. At present there are no projection calligraphic systems in production. Beam penetration is a term used to define the electron beam striking and penetrating the surface of the phosphors on the CRT tube face. By varying the velocity of this beam it is possible to cause it to penetrate to a shallower or deeper level. The two color phosphors on this type of tube provide red and green as well as a yellow-white light output. Blue is missing and causes a serious drawback in beam penetration CRT's. However, recent advances may make blue available in the very near future. Calligraphic means stroke written random scan graphics. Surfaces and lights are generally drawn in the same sequence as they are computed. This is both an advantage and a disadvantage. It simplifies the required complexity of the CGI system. Calligraphic system costs are well below raster scan CGI system costs. The resolution of beam penetration CRT's is generally high and there is no color convergence or fringing problem to contend with. Light output levels, however, are fairly low and because of the lack of blue capability,

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day scenes, when generated, may appear somewhat unrealistic. Contrast ratio in day scenes is fairly low while night scenes have very high contrast. Resolution may approach 2,000 lines while one system can position a point to an accuracy of 4,096 lines with a resolution of better than three minutes of arc.

3.1.2 Raster Scan CRT's

This display technology is used in day, dusk, and night visual systems. This type of display, which is a technological derivative of a standard color television CRT, provides a full color, high contrast, high brightness (luminance) image. The disadvantages of this type of display center around its fundamental structure. A visual scene is a continuous entity. A raster scan CRT image is made of up a series of discrete scan lines. Since by definition the nature of the display precludes presentation of continuous visual information between scan lines, resolution is lost. Additional problems occur because of the scene content itself. If uncorrected, any diagonal line which passes through several raster scans will appear to be made up of a stair step edge rather than be a straight line. This problem can be corrected by a technique called edge smoothing. Another problem which exists is called scintillation. Scintillation is the effect seen when a small object or point light source in a dynamic scene moves from one raster scan to another and disappears in between. The effect is a flashing on and off of the object or point light source. This problem is corrected to a greater or lesser degree in various display systems. Other problems of this type still exist, and they are all grouped under a category called aliasing or "scene anomalies." They are unique and caused by raster scan technology.

As previously stated a raster scan image is made up of a group of discrete rasters or line segments. The number of scan lines often corresponds to the resolution figure raster scan display. For instance, if the horizontal resolution of a raster scan display is 1,000, there are 1,000 discrete points of visual information available in each horizontal line.

A frame is defined as one complete picture. The American standard frame is made up of approximately 525 scan lines. The European standard is 625 scan lines. Some high resolution systems currently have slightly over 1,000 scan lines. A frame may be made up of two or more fields. The American standard is just over 200 scan lines per field, and there are two fields making up a standard American frame. Each field displays alternating scan lines which are painted sequentially. For example, all the odd number scan lines, 1, 3, 5, 7, etc., are painted in order, then all the even number scan lines which go in between the odd number scan lines, 2, 4, 6, 8, etc., are painted. The process of putting these fields together to make a single frame is called interlacing.

3.1.3 Infinity Image for Direct View CRT Displays

The term Direct View is used to describe the screen of a CRT which provides the observed visual scene. This is a real image and, if it were seen without any aid, it would appear to be at whatever physical distance it was from the viewer. Because visual scenes used in training are analogs of the real world situation they provide visual cues which in the real world are located at a good distance from the viewer. If it is desired that the visual information coming from a direct view visual system appears to be at a greater distance, it is necessary to collimate the image. To collimate or straighten the light rays coming from the display creates a virtual image at infinity. This is accomplished by the addition of an infinity optics system. An infinity optics system is comprised of a group of optical elements which may include a spherical mirror and beam splitter. These optical elements can be arranged in line with, or normal to, the face of the CRT. They provide a virtual image of the face of the CRT which appears to be at infinity.

3.2 TV PROJECTION TECHNOLOGY

A second application of raster scan technology is in the field of projection. Here the viewer observes a scene projected onto either a flat or hemispherical screen rather than a direct view of the CRT surface. Projection technology has been used previously where a wide FOV is required in areas such as air-to-air combat. Projection applications have taken two approaches in the past. The first approach has been to provide the viewer with a wide FOV via multiple individual channels or projectors, each having the same angle of coverage. This approach provides no special features for depicting specific targets because the resolution of the entire scene is constant. The second approach recognizes this drawback and separates the scene into background and target information.

3.2.1 Background/Target T.V. Projection System

The Aviation Wide Angle Visual System (AWAVS) is used as an example here. A background scene is provided by a raster scan video projector with an anamorphic lens. The anamorphic lens spreads the image to a greater extent in the horizontal direction than in the vertical direction. For instance, it may provide a 160° horizontal by 80° vertical Field of View. Because the background scene is effectively "stretched" the resolution is quite low. But this portion of the scene is not meant to provide detailed visual cues just as in the case of the Earth/Sky projector. A high resolution target scene is projected onto a blank spot in the background scene. This blank spot has been generated electronically by a video technique called keying. Keying subtracts features found in one scene from an identical area in another scene. The two scenes may then be added together creating a single scene with no apparent superimposition. This type of approach permits the target to be depicted with whatever resolution is required. We will use an example in which a point of light must be movable within a range of 0° 0' 21.6" of arc (0.006 degrees) per raster line. One degree would have 166.6 raster lines in it and a 1,000 raster line system would cover 6 degrees. With a ten to one zoom lens optical system on this target video projector, it is practical to zoom between 6 and 60° or a range of 0° 0' 21.6" of arc through 0° 3' 36" or arc per raster scan.

3.2.2 Projection System Tradeoffs

The following question is yet to be answered. In the LSO trainer application do the advantages of a background/target system outweigh its disadvantages when it is compared to an infinity optics system? Projection systems advantages are as follows:

a. greater potential resolution with a target projector

b. a multiviewer volume

c. space for the LSO instrumentation

d. no gaps or edge matching problems in some configurations

e. unconfined and unobstructed volume giving greater user acceptance and therefore greater training utilization potential.

The potential disadvantages are as follows:

a. significantly higher acquisition cost

b. greater complexity

c. higher maintenance cost

d. lower reliability

e. lower image brightness

f. lower contrast

g. lower background scene resolution

h. non-infinity image (although at ten feet)

i. larger support facility required.

3.2.3 <u>Video Projector Types</u>

In the late 1930s the very first television receivers came into use. These receivers used projection as a means for enlarging the image size because the CRTs of that day were too small for direct viewing by more than one or two people at a time. As CRTs became larger, projection became a thing of the past. In the late 40s, commercial applications for large screen projected television were perceived. Today, projection technology is accomplished through two different approaches.

3.2.3.1 <u>T.V. Projection Approach 1.</u> The first approach is the original approach taken in the late 1930s. An electron beam is modulated and projected onto the inside surface of a CRT to form the normal television image. The image on the face of the CRT is then projected by optical means onto a screen. These optical means may be either refractive optics (a simple lens system) or a Schmidt Optical System which is the same optical system used in some reflecting (Catadioptic) telescopes. Both of these techniques have drawbacks. The light output required from the CRT is so high that there is a heat problem on the surface of the CRT and some method for dissipation must be provided. Secondly, there is an innate alignment problem between the face of the CRT and the optical system. Both of these techniques are highly developed at this time and are used in command and control applications. Advantages of this first video projection approach are that an image may be painted on the CRT screen without any mechanical devices being required as the electron beam is manipulatable via magnetic fields. This approach provides ruggedness and cost effectiveness. However, the light bundle size, specifically in the Schmidt optic design, is so large in diameter that conventional optics may not be used in the light path and a zoom optical system does not appear feasible. One version of the refractive CRT projector uses a sapphire face place because of the high temperatures reached and the need for heat dissipation. This technique is quite expensive.

3.2.3.2 T.V. Projection Approach 2. This video projection approach is called a Light Valve projector. The name was derived from the technique employed which regulates or valves the output of a high intensity light source. Three types of light valves are in production today. Because light cannot be directly controlled via magnetic or electrically charged fields all three light valve projector techniques use the projected images coming from a small CRT to modulate the valve mechanism. In the case of the first two, the light valve mechanism is an oil film. The first oil film projector reflects light from the light source off the oil film (reflective) using the oil film as a mirror. The second passes light through the oil film (transmissive) using the oil film as a shutter. The most recent technological development is the third version of light valve which uses liquid crystal as a reflecting medium. Both of the reflecting techniques are monochromatic and require three channels to provide full color presentations. The transmissive light valve technique, however, provides full color through one channel. The reflective oil film light valve is very expensive, very large and not very reliable although it is capable of the highest level of light output.

3.2.4 TV Projector Criteria

A TV projector comparison must be made using the following criteria.

a. brightness variation across the screen (evenness of illumination)

b. light output in lumens

c. resolution

d. cost

e. operating costs per hour for B&W as well as full color

f. reliability

g. maintenance requirements

h. size and weight

i. light beam diameter (bundle size)

j. video response (bandwidth)

k. power requirements

l. distortion figure (and how measured — geometric distortion?)

m. linearity (as a percentage of display width)

n. contrast ratio

o. line width

p. alignment upon tube replacement

q. radiation and high voltage danger

r. vacuum danger, if any

s. color convergence line width

t. alignment and drift figures

u. fail safe circuitry? — phosphor protection, etc.

v. edge matching in a multiprojection system, estimated degree of difficulty

w. color matching in a multiprojector system, estimated degree of difficulty

x. aging effects on color balance.

3.3 MULTIVIEWER HYBRID SYSTEM

One currently operational hybrid visual system exists (Redifon DUOVIEW) and another has been researched and proposed (GE) to provide a multi-viewer volume in which the scene is visible without distortion or cutoff from various positions. This feature may be necessary because of the LSO expressed desire to have the instructor stand next to the student during parts of training. The optical path works as follows: a video projector projects its image onto a rear screen. This screen is larger than a CRT surface and provides a real image. The screen image is collimated by a mirror and presented to the viewer. The one advantage of this system (large viewer volume) may not be sufficient to justify the system's use. The system has not only the positive features of both infinity optics and projection systems but the negative features as well. Specifically, the higher cost, lower resolution, and lower image contrast. An advantage relative to dome projection systems is the compact size. An advantage relative to other infinity optic systems is the wider viewer volume. A target projector could be added and the background projectors upgraded to overcome the disadvantages of this approach.

3.4 LASER VISUAL SYSTEMS

At the present time there are two visual systems nearing completion which use laser technology as the basis for their displays. Redifon is developing one system in England under subcontract to American Airlines who is prime contractor to the U.S. Army Office of Project Manager for Training Devices at the Naval Training Equipment Center in Orlando, Florida. It differs from the first in several key features. Both systems are intended to give a very wide Field of View. The Redifon system is the Wide Angle Scanned Laser Visual System and provides the observer with a 175° horizontal by 60° vertical Field of View projected onto a hemispherical screen. The Naval Training Equipment Center version is called a 360° Nonprogrammed Visual Display or a 360° Annular Visual System. It provides a 360° horizontal by 60° vertical field of view. The system resolution for the Redifon system is 5 arc minutes. The system resolution for NAVTRAEQUIPCEN is 9 arc minutes with 3 arc minutes between each scan. Both systems will be operational by September of 1978. Both are monochromatic but can be converted to full color. These display technologies provide continuous, high resolution, wide field of view background projection and do not require or employ any additional system for targets. No edge matching problems exist. Five arc minutes may or may not be sufficient resolution for the aircraft in an LSO trainer.

3.4.1 Redifon Wide Angle Scanned Laser Visual System

At present, this system uses a model board as the source for the image generation. Positioned over the model board is a laser scanning device which is called a cameria and is, in actuality, a probe. The probe is used to scan laser light onto the model board. A series of photocells, located behind the probe, then picks up the reflected laser light. These photocells relay their information as composite video signals from a processor to a laser projector. Because this projector is not at the center of a curvature of the spherical screen onto which the image is projected, the projector bounces the laser light off a spherical mirror which corrects for the discrepancy, and onto the spherical screen. It is important to note that a key link in this system is a composite video signal. Though the preliminary system was implemented using model board technology, computer generation of imagery could be substituted at this point in the link. By limiting the field of view to 175° horizontally by 60° vertically, higher resolution has been attained than would have been practical with a 360° horizontal Field of View. The system is also less complex. No luminance figures for the display have yet been published.

3.4.2 NAVTRAEQUIPCEN-360° Nonprogrammed Visual Display (360° annular visual system)

This system which was devised to provide helicopter pilot training in "nap-of-the-earth" techniques is being developed at NAVTRAEQUIPCEN and is almost operational. It differs in certain respects from the previously described Scanned Laser system but also uses a model board. Rather than a probe which scans a laser light onto the model board, there is a bank of lights which illuminates the model board. There is a pickup probe which works in conjunction with a Charge Coupled Device (CCD) television camera to acquire the visual scene from the model board. This probe is of a unique design in that it gathers light in the 360° arc which surrounds it. A multi-faceted prism revolving at a very high speed distributes this light to the CCD array. This visual information is subsequently converted to a composite video signal. The projector utilizes a similar visual system but in reverse to first modulate and then scan with a group of lasers. After passing through this rather complex optical path the laser visuals are projected onto a 360° spherical screen. As previously mentioned, the projected resolution will be approximately 9 arc minutes. The screen luminance should be approximately 10 foot lamberts. The contrast ratio will be between 40:1 and 100:1. Both of these systems provide excellent resolution but may not have adequate resolution to meet the requirements of an LSO trainer aircraft.

3.5 MEASUREMENT OF VISUAL SYSTEM DISPLAY PERFORMANCE

Conventional techniques for measuring the resolution of visual systems do not make those measurements at the viewer's eye point. Focus spot size and the degrading effects of optical elements as well as screens are not taken into consideration. A newer method, the Modulation Transfer Function (MTF), measurement has been developed which does encompass these considerations. Measurement is accomplished by the use of a television camera which takes the place of the viewer's eye at the eye position.

3.6 FOV VS RESOLUTION

3.6.1 Multichannels

There are two methods to increase the FOV of video displays. The first method is to increase the number of displays which adjoin each other and thereby increase the horizontal or vertical FOV. Each individual display is called a channel and a wide FOV system may have as many as seven or eight channels. The problems associated with this type of approach are in the areas of edge matching, color matching, and luminance matching. This approach causes no decrease in background scene resolution as occurs with anamorphic optics, but neither does it increase target resolution.

3.6.2 Single Channel Wide FOV

This approach has been used in a projection system, but could be used with an infinity optics/projection system. It takes one channel of information and stretches it to fit the required FOV. This is done optically through the use of an anamorphic lens. The standard aspect ratio of a video channel is 1.33. The aspect ratio is defined as the ratio of the width to the height. For instance, a standard visual system channel is 48° wide by 36° high. Another combination which can be used is 40° wide by 30° high. The ratio remains the same (1.33). When an anamorphic lens is used, it changes the aspect ratio by taking the 1.33 aspect ratio image found at its focal plane and spreading the light out to fill the screen as required. For instance, if the field of view is 160° by 80°, the aspect ratio has been changed to 2. This causes a loss of resolution and luminance, but works well for a background scene. If a target projector is then added to provide a high resolution target a full capability Image Display system is realized. One caution is in order, target image resolution may be excellent, but positional accuracy is the real limitation when a servo-driven, moving target projector is employed. A fixed target projector could be an alternative.

3.7 STEREO VISUAL TECHNIQUE

A technique is now under development at the Naval Ocean Systems Center (NOSC) for providing stereoscopic (binocular) information to the viewer using a standard 2 to 1 interlace raster scan technology. Left eye, right eye information is provided by encoding it into the odd and even fields of a standard 2:1 interlace raster scan CRT. Decoding is accomplished by the switching on and off of the views seen by the right and left eye of the viewer. The switching is accomplished through the use of PLZT ceramic eye glasses. These eyeglasses switch at the field rate, blanking the left eye when the right eye field is being displayed on the CRT screen and blanking the right eye when the left eye field is being displayed. In effect, the eyeglasses operate as sequential shutters for the right and left eye. A distance scene of San Diego Bay was observed. The stereo effect was very strong but the visual cues were misleading because it had been necessary to place the two cameras much farther apart than the human eyes in order to provide the stereo effect. There is some question as to what stereoscopic information, if any, would be available had this not been done. Apparent light loss was very high (83%). It does not appear that this technology is justified for the LSO trainer.

SECTION 4

VISUAL SIMULATION INDUSTRY OVERVIEW

This section is meant to be an introductory guide to some current visual system hardware.

4.1 VIDEO PROJECTORS

- Catadioptic Video Projector. General Dynamics Electronics Division has developed a large screen projection display system using a high a brightness CRT coupled with a mirror lens (Catadioptic) optical system. This projector is capable of either 525 lines standard broadcast television projection or 1225 line high resolution industrial format. Even higher line counts and resolution are said to be possible. The light output of a single monochromatic projector is equivalent to 800 lumens with a contrast ratio of 12:1. A screen gain of 1.8 provides 40 foot lamberts of luminance from a rear screen. This is a fairly rugged projection system with an estimated life of 2 to 4,000 hours, a CRT replacement cost of $2 to $3,000 and an operating cost per hour of $0.50 to $1.50.

- Refractive Video Projector. Ford Aerospace and Communications Corporation has developed a refractive video projection system. A single channel version is capable of a 280 lumens light output. Its contrast ratio is 8:1 (measured on a unity gain front projection screen with an ambient of 2.2 foot candles on the screen). The video bandwidth is 40 MHz and it is capable of either 525 lines or 1,029 lines. A three channel full color version is available. The approximate price is $225,000. Screen luminance with this unit in the same configuration as a single channel is 20 Foot-Lamberts in comparison with 16 Foot-Lamberts for the single channel. A third version of this projection system is a redundant color system offering a screen luminance of 41 Foot-Lamberts under the same conditions. It uses six projectors, two for each color. The Mean-Time-Before-Failure (MTBF) of the single channel system is estimated to be greater than 1200 hours and the Mean-Time-To-Repair (MTTR) is estimated to be less than 30 minutes, with a plug-in replacement being the preferred method of repair. The estimated range for CRT life is from 500 to 2,000 hours with a replacement cost of $10,000 to $30,000 and an operating cost per hour of $5.00 to $60.00. The six-projector version which is called the six pack costs approximately $500,000. Lens costs drop dramatically in quantity and these prices are only approximate.

- Reflective Light Valve Projector. Gretag/Eidophor is the oldest commercially successful light valve projector manufacturer. Three standard versions are available with one or more special versions which provide sequential color capability. Model 5180 is a monochrome projector with a light output of 4,000 lumens and Model 5170 is a color projector with a light output of 3,600 lumens and Model 5171 is a color projector with a light output of 7,000 lumens. Both color projectors use three simultaneous channels to provide red, green and blue. Resolution for all three projectors is specified at 800 TV lines in a horizontal direction (pixels). A contrast ratio of 100:1 is claimed but is probably not measured at the screen or with any ambient light. The maximum scan rate is 1,029 lines, 50 field/second, 2 to 1 interlace, or 945 lines, 60 fields/second, 2 to 1 interlace. The video bandwidth of the three projectors is 21 MHz. This projector system is physically quite large and quite complex. It requires a high level of expertise for maintenance purposes and has an estimated life of 1 to 3,000 hours with a replacement cost of approximately $13,000 and an operating cost of approximately $4.30 to $18.00 an hour for the monochrome projector.

- Transmissive Light Valve Projector. General Electric has developed a compact single channel monochrome and single channel color series of light valve projectors. The monochrome projectors are the PJ 7000, 7010, 7,100. Their horizontal resolution is typically 1,000 TV lines (minimum 700 TV lines or pixels). The PJ 7000 and PJ 7010 will project either 525 line x 60 fields per second or 625 lines by 50 fields per second. The PJ 7100 operates at 1,023 lines by 60 fields per second standard. The light output is typically 750 lumens with minimum of 600 lumens and the contrast ratio is claimed to be 100:1 with a minimum of 75:1 in negligible ambient light situations. The PJ 5000 series of color video projectors includes the PJ 5000 with a 525 line by 60 fields/second capability and the PJ 5100 with a 1,023 line by 60 fields/second capability. The PJ 7000 sells for $48,500. The PJ 7010 sells for $48,500 and the PJ 7100 sells for $52,000. The PJ 4000 sells for $55,000 and the PJ 5100 sells for $72,500. Estimated life is 500 to 2,000 hours with a replacement cost of $3,000 to $15,000 and an operating cost ranging from $1.50 to $20.00 an hour.

- Liquid Crystal Light Valve Projector. This is a developing technology being investigated by Hughes Aircraft Company. Research began in Hughes Research Lab in Malibu, California in 1970 and was turned over to the industrial products division in 1976 for production. The first production version was designated the HDP 2000. It delivers greater than 1,000 lines of resolution at 1500 lumens. A modified version of this projector is going to be installed in the NASA Shuttle Mission Simulator (SMS) by December of 1978. The Air Force Human Resources Laboratory (AFHRL) under project 1958 has also funded the development of a full color version of this liquid crystal light valve technology. This prototype projector has already been delivered to AFHRL and is under evaluation. It should be noted that this is a developing technology. It has one capability unavailable in any other light valve video projector. That capability is random scan graphics. It also has the potential for higher light ouptut and resolution than it is now delivering and could be appropriate for use in both high resolution target projection and high resolution background projection.

4.2 FULLY INTEGRATED VISUAL SYSTEMS

4.2.1 Advanced Technology Systems (ATS) - A Division of the Austin Co. ATS is developing a real time CGI capability. To date only static scenes have been demonstrated. A demonstration of real time capability is anticipated before the end of 1978. The following are ATSs stated goals for CGI.

Image Generation

- COMPUTROL

Day/Dusk/Night
Total Data Base: Virtually no limit
Active Data Base: 30,000 edges or 7,500 point lights
Color: Full color
Channel Count: Expandable to 8

Image Display

- Direct View CRT

Infinity Optics
Single Viewer volume
Full color
Raster Scan: 1,029 line rate, 30 frames/second
FOV: 48° horizontal, 36° vertical
Highlight Luminance: 77 Foot-Lamberts at CRT surface

- Projection Video

Implementable

4.2.2 General Electric

Image Generation (CGI)

- COMPU-SCENE

Day/Dusk/Night
Total Data Base: Up to 20,000 edges and 4,000 point lights
Active Data Base: 1,000 - 3,000 (8,000 claimed)
Lights: 2,000 - 4,000
Color: Full Color
Raster Scan: 1,000 lines
Horizontal Resolution: 1,023 Pixels
Occultation: 8 levels
Circles/arcs: Under development
Texturing: Under development

Image Display

- Direct View CRT

Infinity Optics	
Single Viewer	
Full Color	
Raster Scan:	1,000 line
FOV:	40° horizontal, 30° vertical
Resolution:	3.8 arc min. (std), 2.7 arc min (high)
Highlight Luminance:	6 Foot-Lamberts

- Aviation Wide Angle Visual System (AWAVS)

Background Projector	
FOV:	160° horizontal, 80° vertical
Resolution:	15 — 30 arc minutes per line pair (center-edge)
Highlight Luminance:	6 Foot-Lamberts
Shades of Gray:	10
Raster Scan:	525 — 1023 (variable), 825 nominal
Bandwidth:	4 — 30 MHz (variable), 20 MHz (nominal)
Target Projector	
FOV:	60° H x 40° V 6.6° H x 4.2° V } Zoom range
Resolution (max zoom):	1.5 arc minutes per line pair
Resolution (min zoom):	12 — 15 arc minutes per line pair (center-edge)
Highlight Luminance:	6 Foot-Lamberts
Shades of Gray:	7
Raster Scan:	525 — 1023 (variable), 825 (nominal)
Bandwidth:	4 — 30 MHz (variable), 20 (nominal)

4.2.3 Link Division, The Singer Company

CGI

- VISULINK

Documentation inadequate to assess current technology
8,000 Edge system available.

4.2.4 Marconi Radar Systems Limited

Image Generation (CGI)

- TEPIGEN

Day/Dusk/Night	
Total Data Base:	1,000 — 5,000 surfaces
Active Data Base:	400 — 2,000 surfaces
Color:	Full color, 262,144 hues, 64 per frame

Horizontal Resolution:	350 Pixels
Occultation:	64 levels
Texturing:	Implemented

Image Display

- TEPIGEN

Raster Scan:	625 line
Projection system	
FOV:	40° vertical by 30° horizontal per channel

4.2.5 McDonnell Douglas Corporation

Image Generation (CGI)

- VITAL IV

Night/Dusk/Day (Quasi)

Total Data Base:	15,000 surfaces, 400,000 light points
Active Data Base:	300 surfaces, 8,000 light points
Color:	Light Points and Surfaces; 10 hues ranging from Red to Green, No Blue yet
Resolution:	3 arc minutes
Positional Resolution:	4,096 x 4,096 locations

1 Bay of Electronics Hardware

Image Display

- VITAL IV

Infinity Optics
Single Viewer Volume
Beam Penetration CRT (Calligraphic)

4.2.6 Redifon Simulation Inc. (Visual System Hardware)
Evans & Sutherland Inc. (CGI-DAYNITE Software)

Image Generation

- Camera Model System

Closed Circuit Television (CCTV)

- CGI

NOVOVIEW

Night/Dusk only

Data Base:				
Edges:	64	128	192	256
Light Points:	6,000	5,300	4,600	4,000

1 Bay of Electronics Hardware
4 colors for lights — Light Points only (no Blue yet)
Red
Green
Orange
Yellow-White
200 surfaces — 64 shades of gray
Occultation
FOV: 48° horizontal x 36° vertical

DAYNITE (Evans & Sutherland)
Day/Dusk/Night

Total Data Base:	2000 polygons (faces)
Active Data Base:	800 polygons (faces)
Lights:	2000
Colors:	Full color, 250 hues
Raster Scan:	625 lines
Horizontal resolution:	700 pixels

Occultation

Image Display

- NOVOVIEW NIGHT ONLY DISPLAY

  Same hardware as MONOVIEW except
  Beam penetration CRT (Calligraphic)
  Used in conjunction with NOVOVIEW CGI
  Luminance: 18 Foot-Lamberts at CRT Face for point lights

- MONOVIEW
  Infinity optics
  Single viewer
  Full color
  Raster Scan CRT — 625 line
  Used in conjunction with DAYNITE CGI

- DUOVIEW
  Infinity optics

Large Viewer Volume:	Two-1 foot diameter spheres whose centers are 3 feet 6 inches apart jointed by a 1 foot diameter cylinder positioned 2 feet 3 1/2 inches from bottom of collimating mirror
FOV:	60° diagonal, 3:4 (1.33) aspect ratio
Resolution:	300 — 500 pixels
Projector output:	165 lumens
Luminance:	6 Foot-Lamberts
Contrast Ratio:	75:1 minimum

  GE Light Valve video projector

ACRONYMS

ACLS	Automatic Carrier Landing System
ACM	Air Combat Maneuvering
AAFTS	Automated Adaptive Flight Training System
AOA	Angle of Attack
APC	Automatic Power Compensation
APCS	Automatic Power Configuration System
AWAVS	Aviation Wide-Angle Visual System
B/A	Basic Angle
B/U	Back Up
CATCC	Carrier Air Traffic Control Center
CCA	Carrier Controlled Approach
CCD	Charge Coupled Device
CGI	Computer Generation of Imagery
CIG	Computer Image Generation
CLARA	Pilot Cannot See Meatball
CNAL & COMNAVAIRLANT	Commander Naval Air Forces Atlantic
CNAP & COMNAVAIRPAC	Commander Naval Air Forces Pacific
CNATRA	Commander Naval Air Training
CQ	Carrier Qualification
CRT	Cathode Ray Tube
DIG	Digital Image Generation
DLC	Direct Lift Control
FCLP	Field Carrier Landing Practice
FLOLS	Fresnel Lens Optical Landing System
FOV	Field of View
GCA	Ground Controlled Approach
HPRI	Human Performance Research, Inc.
H/R	Hook-to-Ramp
HUD	Heads up Display
IES	Interactive Experiments System
ISD	Instructional System Development
IWR	Isolated Word Recognition
LCSR	Limited Continuous Speech Recognition
LSO	Landing Signal Officer
MOVLAS	Manually Operated Visual Landing System
MTF	Modulation Transfer Function
NATOPS	Naval Air Training and Operating Procedures Standardization
NORDO	No Radio
NAVTRAEQUIPCEN	Naval Training Equipment Center
PA	Public Announcement
PAR	Precision Approach Radar
PLAT	Pilot Landing Aid Television
R/A	Roll Angle
R/T	Radio Terminology
SQDN	Squadron
SUS	Speech Understanding System
VCD	Voice Data Collection
W/O	Waveoff
WOD	Wind-Over-The-Deck

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