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MULTIPLE MAN-MACHINE INTERFACES

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SUMMARY

Modern technology has produced machines that, in many instances, can see, hear, and touch with greater accuracy and precision than human beings. Consequently, the military pilot is more a systems manager, often doing battle against a target he never sees. This paper explores the multiple man-machine interfaces inherent in military pilot training, their social implications, and the issue of possible negative feedback.

INTRODUCTION

A man-machine system is a combination of one or more human beings and one or more physical components interacting to bring about, from given inputs, some desired output. Man interacts with the system to fulfill the function for which the system is designed.

Ever since prehistoric man discovered the wheel and other "necessary inventions," man-machine interfaces have proliferated. Nowhere today is this more evident than in the multiple machine interfaces with which the military student pilot must contend. Modern technology has produced machines that, in many instances, can see, hear, measure, and touch with greater accuracy and precision than human beings. Consequently, the military pilot is more a systems manager, often doing battle against a target he never sees.

Although many of the same interfaces are faced by flight crews and multi-engine pilots, this paper will address only the multiple machine interfaces encountered by the undergraduate jet pilot trainee, a one on one situation.

Current plans are underway to upgrade military training aircraft in order to facilitate the student's transition to the highly sophisticated tactical aircraft. Not only must the student contend with complex display symbology, formatting, and data rate, but increasingly more of his training takes place in devices that are, in some ways, more sophisticated than the aircraft itself. His academic training is effected largely through computer-assisted instruction, often combined with video disc technology. This system is linked to a computerized training management system which combines management and scheduling functions with information storage and retrieval. In addition, both the aircraft and the training devices are equipped with performance measurement equipment which records the student's every movement.

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Today, we joke about the scarf, goggles, and needle-ball indicator era, but that has a core of truth. In the early days of flying, when the flying machine was relatively simple (figure 1), the man-machine interface was straightforward. Superchargers and oxygen systems were non-existent. Rarely out of sight of land, the pilot used railroads, rivers, and other distinctive landmarks as navigational guides. His instruments were simple - - perhaps a compass, altimeter, needle-ball indicator for horizontal reference, air speed indicator, fuel gauge, and oil pressure gauge (figure 2). Dead reckoning or "seat-of-the pants" flying was the norm. There were no radio communications. The pilot was in control (figure 3).

Three-quarters of a century later, aviation has changed drastically. As man's knowledge of aerodynamics, aircraft structures, and electronics has increased, airplanes have developed accordingly. Because modern aircraft are complex, with many separate systems to be monitored, their crowded cockpits contain numerous readouts. Because panel space is often insufficient, space-saving devices such as two or three pointer instruments have been introduced. However, often these innovations are at the cost of reading difficulty and therefore may cause increased errors.

Today, cathode ray tube displays (CRT) permit the display, as on a television screen, of only the information which is currently required. Alternatively, basic flight information may be superimposed on the real world by a head-up display (HUD) which projects the CRT image on a screen in front of the pilot. The HUD permits the pilot to maintain his view of the real world and still receive vital information without having to look down at the instrument panel. It has an additional advantage of superimposing

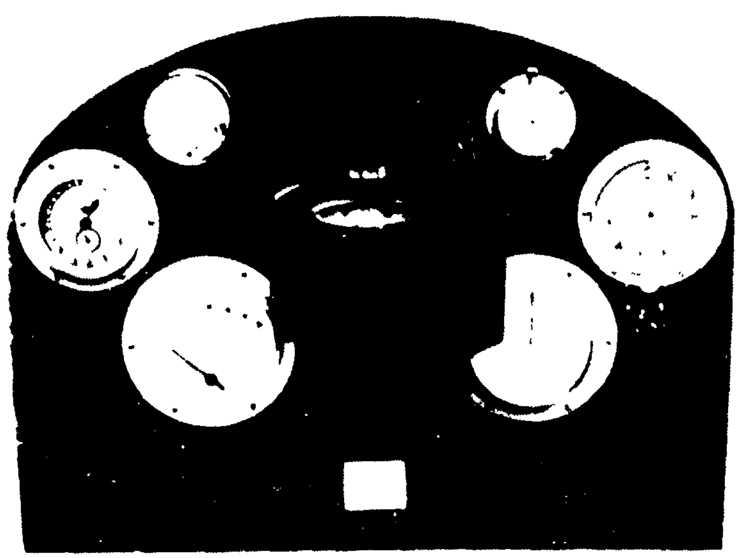

Figure 1. Early Cockpit - Very Simple

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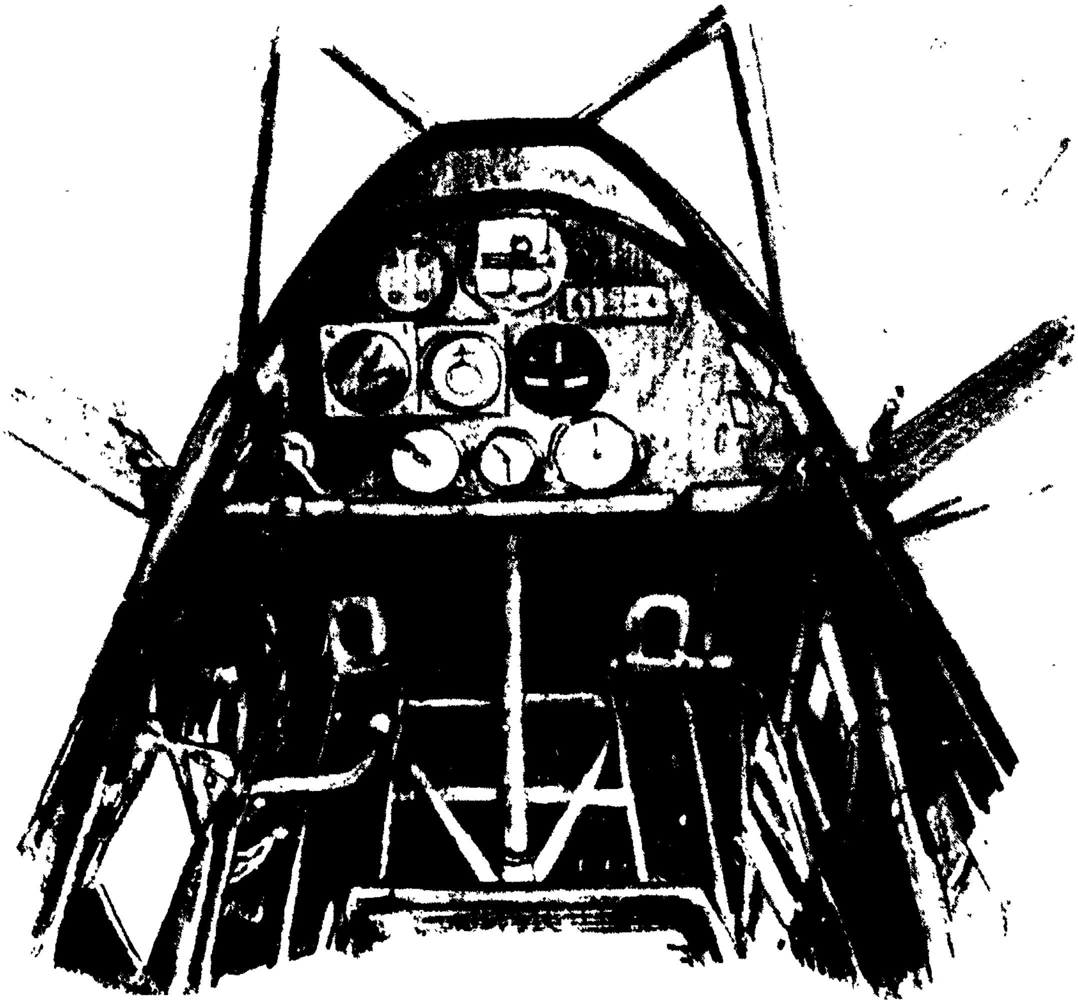

Figure 2. Sketch of Early Instrument Panel

the real world on the synthetic picture collimated to infinity so that the pilot does not have to change his focus. However, an inadequate field of view of the real world results in HUD clutter.

A helmet-mounted sight provides a simple display in front of the operator's eye, and is designed to improve his ability to aim weapons or sensors at potential targets by merely looking in the target's direction. Sensors on the helmet feed data to a computer which calculates where the pilot is looking. The helmet-mounted display is a more complex device which produces an instrument display in front of one of the pilot's eyes.

Despite the growing awareness that there is a tendency to put too much information on the display, an airplane such as the F/A-18 weapons system

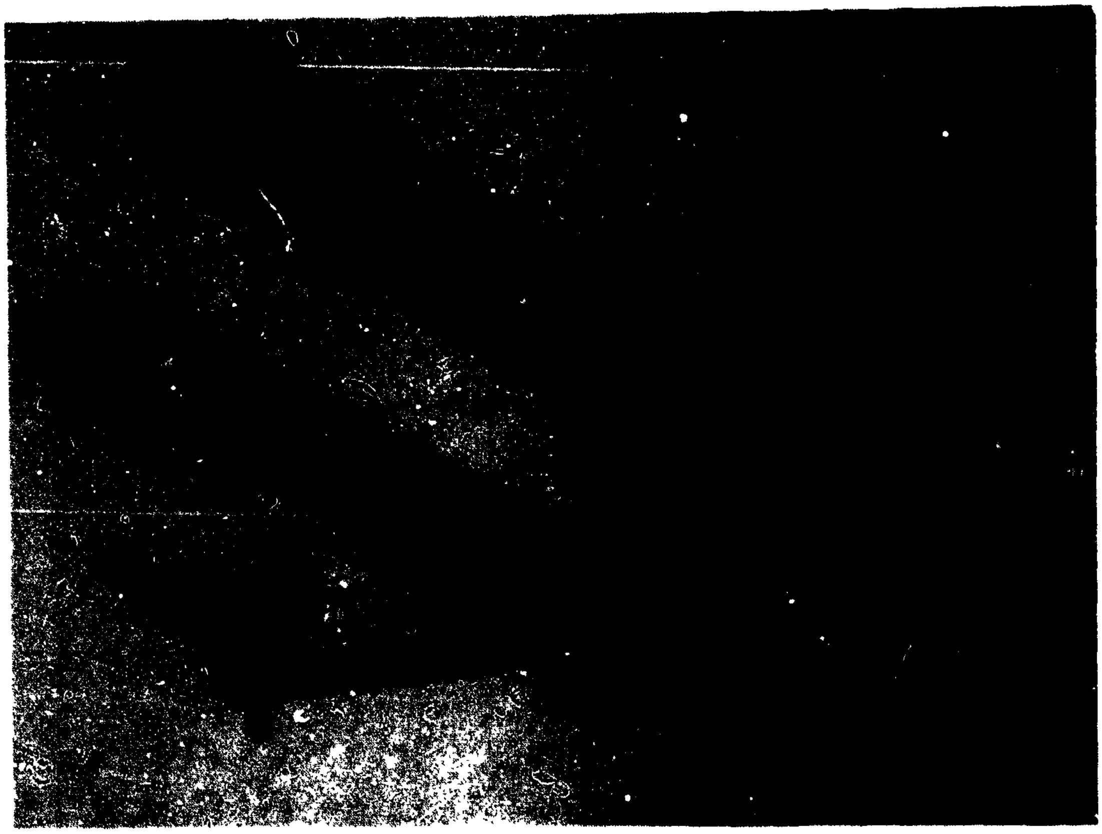

Figure 3. Early Trainer

has a capability of over 700 display symbols which the pilot must learn to interpret, integrate, and act upon (figure 4). Cognitive factors such as man's ability to cross-check several displays for inconsistencies, and to perform mental computations and make rapid judgements under stress must be considered. There are questions as to whether all the displayed information is necessary to a pilot, whether it is correct, or how much of it can process. It is not always necessary to know the precise state of the system, rather whether the system is within limits. And, even when the pilot must know the precise value of the parameters he is monitoring, he may need to check it only once or twice during the flight. Although the human information processing system (figure 5) is analogous to an electrical communications system, man is essentially a single channel device with a processing rate of approximately two bits per second. It may be pointless to present him simultaneously with all the information he may need throughout an entire flight when he can process only a relatively small amount of that information at a time.

Ongoing work in training technology includes a refinement of speech synthesis, speech recognition and speech digitizers along with increased capacity artificial intelligence and computer-aided decision making. The relative merits of such new technology -- the value of speech recognition,

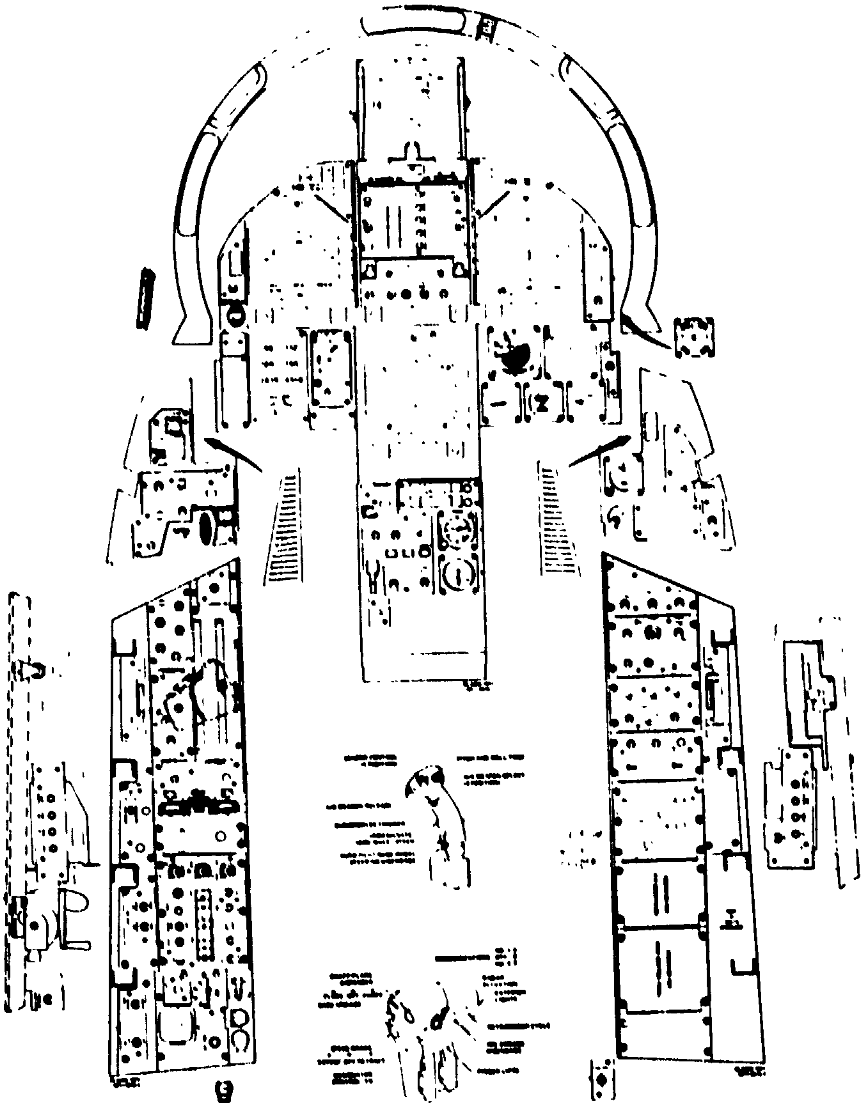

Figure 4. F-18 Crew Station

the merits of CRTs with side switches versus touch panels for controls, the value of pictorial formats such as pathways in the sky, and the feasibility of combining traffic information, weather radar, and a map display on the electronic horizontal situation indicator without information overload -- have yet to be determined (figure 6).

Some experts predict that the future pilot will be presented with more and more information which will be utilized less and less. And, as the cost of displays escalates and the pilot's work load increases, the overall efficiency of this man-machine system will decline due to the shortcomings of many of the new display devices with regard to man's capacities (figure 7).

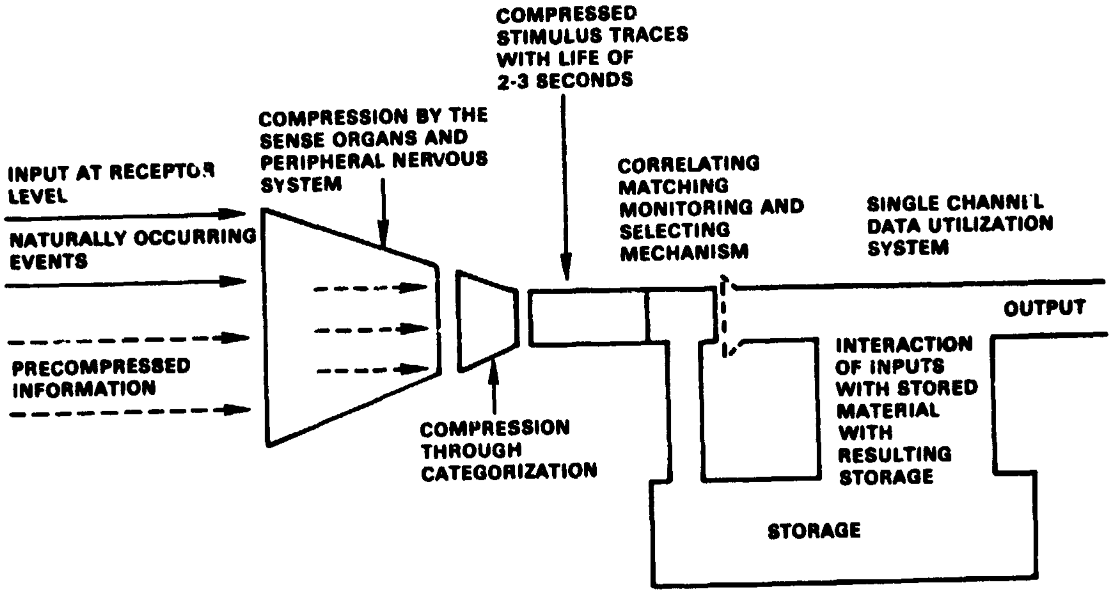

Figure 5. Information Processing

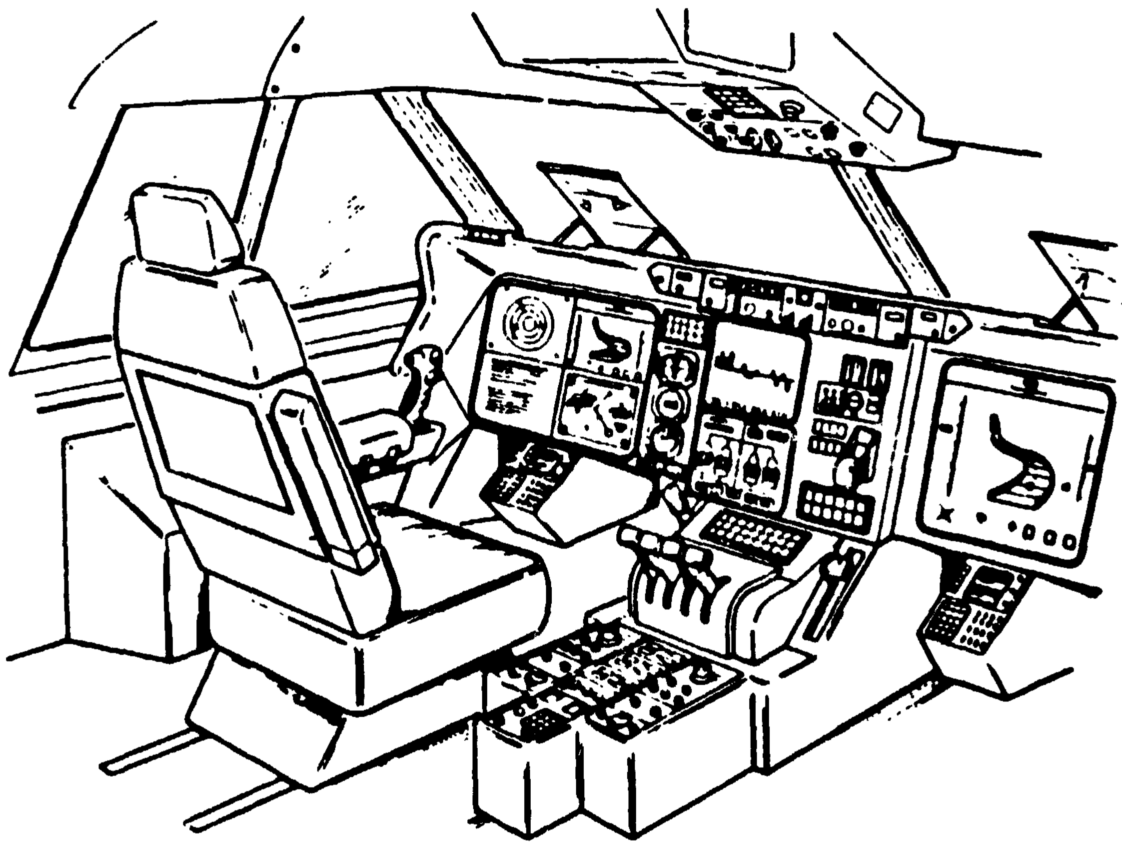

Figure 6. An Advanced Concepts Flight Station

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Figure 7. Cockpit of the Future if Present Trend Continues

FLIGHT SIMULATORS

Along with that of the aircraft, the technology of modern flight trainers (simulators) has been evolving for at least six decades. Unlike today's systems which simulate flight and field of vision with realism or fidelity, the early simulation devices were designed primarily to assess the student's suitability for flight training and his resistance to loss of equilibrium (figure 8). As technology advanced, simulators came closer to replicating actual aircraft. A wide variety of sophisticated systems and subsystems became available for integration into training devices. Through incorporation of advanced instructional features such as problem freeze, performance replay, malfunction insertion, and automated performance measurement, today's simulators provide capabilities for improved instruction. In addition to furnishing training and practice in flying maneuvers which cannot or need not be taught in the aircraft, state-of-the-art simulators can be used as teaching tools rather than as substitute aircraft. However, the value of the expected training benefits to be achieved by the inclusion of many of the options in the trainer must be determined.

Figure 8. Vintage Trainer

VISUAL DISPLAYS

The development of wide field-of-view visual displays which rely upon control capabilities provided by digital computers has introduced a new area of technology into training simulation. The TV-model board, the oldest of current visual display systems, involves a model terrain board and a TV camera. The camera is driven across the model board by a computer as the aircraft it simulates performs various contact maneuvers. Projected imagery displays involve the use of either a film, a model, or a computer-generated image to furnish the display input which is processed electro-optically and projected onto a curved or dome-shaped screen so that the pilot views the display as he would from the cockpit of an aircraft. Dome-type visuals are used in situations where good quality detail is important and judgements of range/range-rate are important -- air combat maneuvering, formation flight, and aircraft carrier landing training (figure 9).

Computer-generated imagery (CGI) visual systems involve computerized simulation of a visual environment through the use of lines or edges presented on a cathode ray tube or by discrete point light source elements controlled

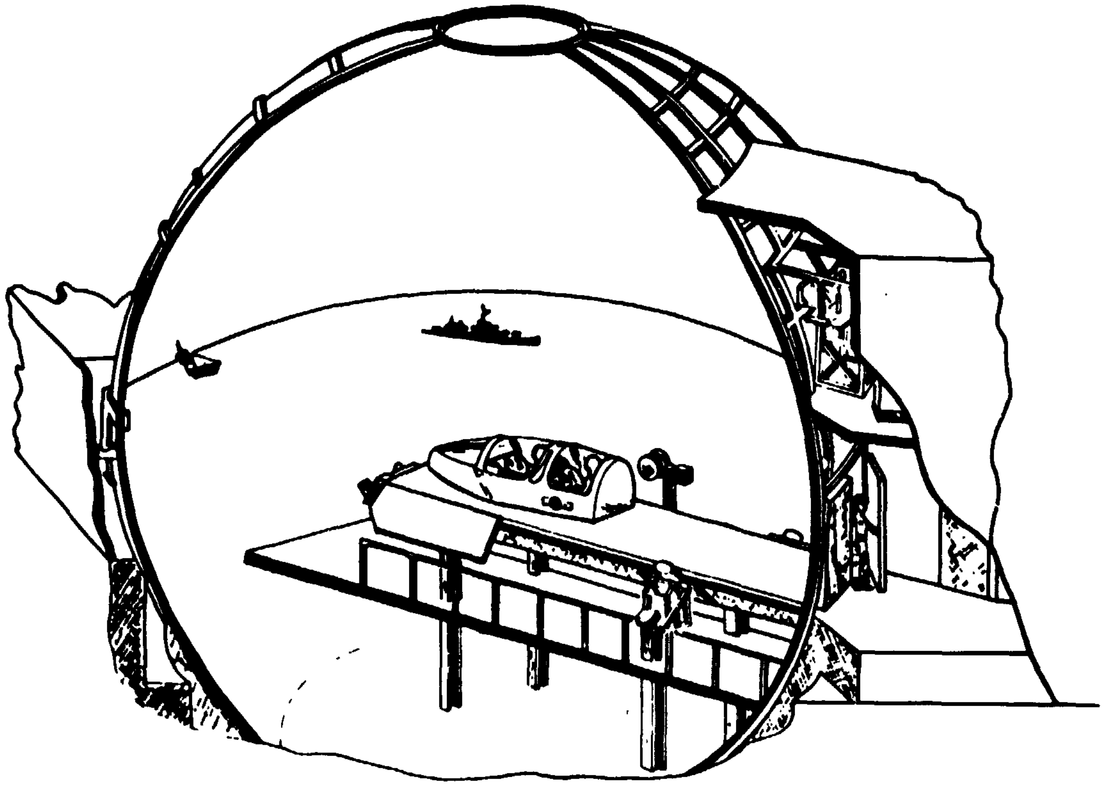

Figure 9. Dome Visual Simulator

to form the in-flight visual environment. Theoretically, this can support instruction and practice of an unlimited variety of training tasks. Dynamic changes in the CGI display are controlled by the simulator's central digital computer.

Cost of current visual simulation systems can exceed six million dollars. Despite this, these systems offer the possibility of substantial cost savings in a pilot's training cycle, especially when replacing those aircraft which have high operating costs. Although there is evidence that positive transfer of training occurs for even the crudest of visual scenes and that visual simulation training aids the student to transition effectively into the airborne environment, studies have also concluded that full fidelity simulation is not necessary for effective transfer of training.

MOTION SIMULATION

Today, there are a variety of devices which can provide motion simulation for a simulator. These include platform motion systems, g-suits and g-seats, stick shaker, and buffet/vibration systems. They are designed to provide either onset or sustained motion cue information to the pilot. The g-seat is an alternative motion cueing system in which air or fluid controls the inflation and deflation of cells in the aircrew seat pan and seat back panels to create and relieve pressure on the pilot's back, buttocks, and thighs, analogous to sustained g-forces during higher performance maneuvers (air-to-air combat maneuvers and air-to-surface weapon delivery).

Although simulator manufacturers continue to urge use of motion systems which may add at least 10 percent ot the initial and operating costs of the device, it has been established that complex cockpit motion is not essential for effective simulator training. It has been pointed out that pilots have been acquiring flying skills with the aid of fixed base devices for years.

Recent studies have further shown that cockpit motion has such a minimal effect on training transfer that it is difficult to measure its contribution. However, due to difficulty in quantitatively assessing fidelity requirements, it is predicted that simulators will continue to be procured under the design goal of maximum fidelity which means, among other things, costly motion systems.

Most recent studies document the fact that flight simulators do not have to duplicate the aircraft in order to be training effective. However, even without costly studies, it is apparent that full fidelity simulation, both visual and motion, is not necessary for training many flight tasks.

COMPUTER-ASSISTED INSTRUCTION

Today's training buzz word is CAI or computer-assisted instruction. In CAI, all instructional materials, i.e., lessons and tests, are stored in the computer. The student interacts with this material in real time via a terminal and display system. The computer can diagnose student performance, prescribe lessons, maintain records of student progress, and predict individual course completion. A decade ago, it was boldly predicted that CAI was going to revolutionize the learning process. It didn't quite accomplish that. Because it takes an experienced author more than fifty hours of writing to produce one hour of courseware, CAI has yet to develop as much courseware as had been predicted. High hopes have alternated with disillusionment at the unimaginative use of computers for electronic page turning.

We are told that computer cost-effectiveness will double every two years through the 80's. Now the availability of low cost powerful standalone computers has renewed interest in CAI. Other positive elements are the availability of new programming languages, the video disc, greater insight into the learning process, and an understanding of the limitations of computers. There are, however, drawbacks.

The efficacy of CAI for general education has not been demonstrated to be superior to any other method of teaching. In the military, it has been noted that student attrition appears to increase with CAI or with computer managed instruction. Generally, military instructors are not favorably disposed toward CAI. Studies on the effectiveness of CAI in the military indicate that it saves about 30 percent of the time required by students to complete the same courses taught by conventional instructional methods. However, CAI saves little time over individualized instruction. And, it is estimated that up to 1000 hours of effort must be expended to prepare one hour of courseware for academic material for a flight training program.

In projected flight training programs, more than 30 percent of the student's time in the academic curriculum is spent in front of a cathode ray tube. In addition, from 20 to 25 percent of his simulator training is conducted in a dynamic cockpit procedures trainer which features a giant CRT screen (figure 10). Thus, in this integrated training program, the student pilot spends over 30 percent of his training time in front of a keyboard and one or two display screens. The second display screen is necessary to carry the video disc output which is controlled by the CAI (figure 11). Lessons stored on floppy discs are presented as text and graphics on one display while static and visual depictions are presented by the video disc player on the other display. The CAI provides immediate feedback to the student, and has a built-in performance measurement capability.

TRAINING MANAGEMENT SYSTEM

Each CAI terminal is interfaced by direct data link to a training management system (TMS) which permits two-way information flow. The TMS provides student history, lesson history, identity and availability, scheduling information, student testing, performance measurement, data base interaction, information retrieval, and any number of reports or inputs for reports.

PERFORMANCE MEASUREMENT SYSTEM

In addition to the academic performance capabilities of the CAI and TMS, in-flight performance is measured in the training aircraft by the performance measurement system (PMS). Data gathering is accomplished both by video recording and digital parameter recording. Aircraft flight parameters in specific training situations such as takeoff, approach, and landing, aerobatic maneuvers and instrument flight are recorded. The video recording system records the HUD field-of-view, including HUD symbology and real world view. At debriefing, these cues are presented to the student along with his performance responses which have also been recorded.

Provisions are included in the system for the instructor to call for special snapshot displays to read the value of certain parameters at a specified moment. And, he can also record his evaluation of the student's performance with respect to certain criteria.

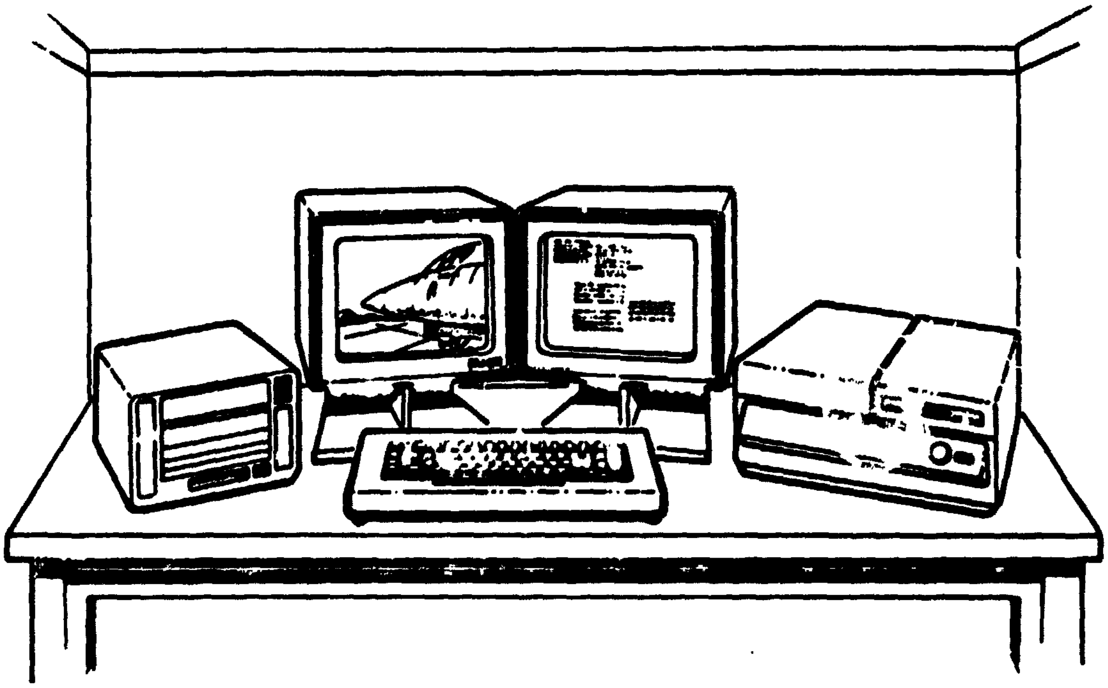

Figure 10. Computer-Assisted Instruction Carrel With Interactive Video Disc

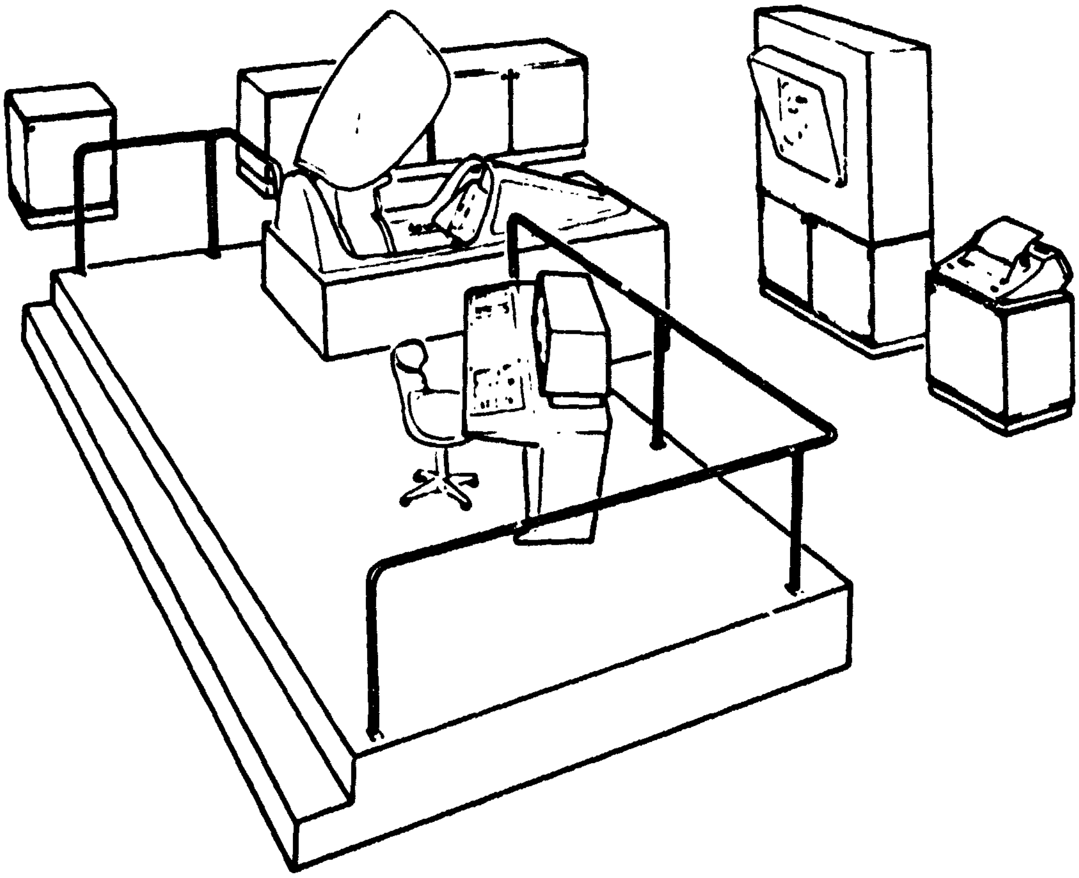

Figure 11. Cockpit Procedures Trainer With Computer-Assisted Instruction

Additionally, all of the performance data recorded for simulator training are interfaced with the TMS. Student performance can be stored in the simulator off-line or real time. The off-line model is of little value for training, however, because the necessity for off-time processing causes feedback delays. On the other hand, real-time measurement offers immediate feedback. However, the requirements for real-time performance measurement implementation are greater because the scoring algorithms must reside on line with the basic simulation program. This requires sufficient memory core and sufficient spare time so that the software can be raised without interfering with the basic simulation program. In addition, sufficient peripherals are necessary so the results can be displayed and stored.

This brief overview, while not addressing, in any depth, the technical intricacies of the TMS and PMS, further exemplifies the multiple man-machine interfaces in pilot training, and the sophistication which may seem to take for granted.

PILOT ACTIVITIES

All human actions can be understood as attempts to achieve a goal; only in this light do they belong together as a related sequence with a definite start and a definite end. To achieve his goal, the pilot engages in two major kinds of activities -- discrimination and manipulation. He must make a series of discriminations -- directional, height or altitude, temporal, and mechanical -- among courses of actions, selecting those which will lead to the accomplishment of a flight mission. The result of these discriminations are subgoals. Manipulation is a psychomotor process which involves moving the airplane's controls in a way that the subgoals needed to execute the mission are accomplished (figure 12).

As part of a system, the pilot does not act in isolation, but receives a continuous stream of inputs in the form of signals, messages, reports, instrument indications, control pressures, and other stimuli. These inputs are combined, interpreted, compared with stored inputs in memory, and transformed into outputs in the form of motor acts and aircraft control movements. More and more, however, the inputs are combined, interpreted, and compared by machine.

The interest of flight training system designers is sometimes linked to statements about how the complexities of modern aircraft cause pilots to make errors. In truth, we are concerned with any pilot error which may occur because of poor training, lack of training, inadequate means for presenting the pilot with information, or controls which are difficult to use. Keeping in mind the cognitively-oriented information processing aspect of the pilot, our interest lies in the fact that the human being is only one element in the system. And, as the trend toward automation continues, the question of man's appropriate role in systems looms large. This has led to consideration of the "Mission Management Control" concept

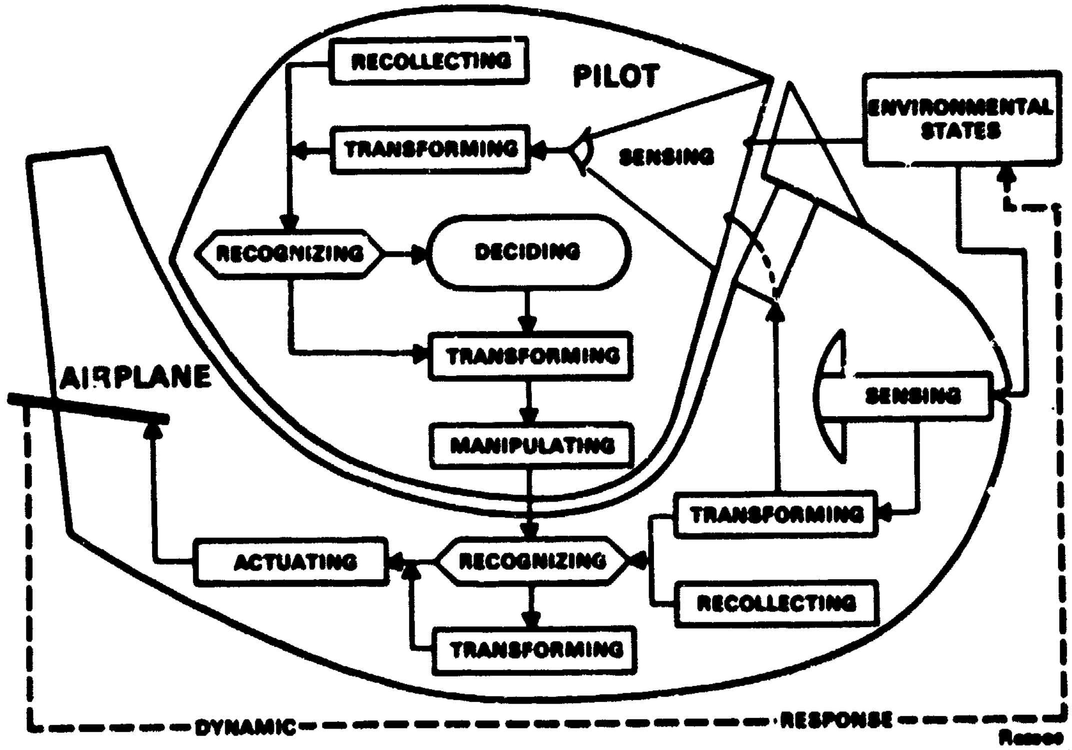

Figure 12. Functional Model of Pilot-Airplane System

wherein the computer presents to the operator a binary "accept" or "reject" solution. The concept essentially takes the operator's brain work out of a problem until the final decision is required. Again, this concept emphasizes the pilot's role as an information manager and final decision-maker.

The pilot in a one-on-one training situation must not be treated as an unthinking, unfeeling, programmed robot. In training, as in any operational situation, we must be certain that man drives the system rather than the other way around. This is the first prerequisite in the process of creating systems and situations for maximum utilization of human talents with corollary human satisfaction in personal accomplishment. Judgement, multimode capability and adaptability, man's contributions to a control system, permit the design of systems with great flexibility and reliability -- and humanity.

CONCLUSION

We have spent considerable time delineating the multiple man-machine interfaces inherent in military jet pilot training. In the search for new and better ways of guiding, monitoring, recording, and evaluating the student's every move, we have virtually eliminated human instruction. We have shown the complexities of the cockpit and simulator, and examined the attendant stress upon the human information processor. We have addressed the one on one student pilot situation, but much of the same applies to the flight crew situation.

It is obvious that we have come to the end of the streamgage and knob era in aircraft displays and controls. We have entered an era where displays take over more of the routine of mission planning, checklists, enroute checks, etc., and where tactical options and emergency assessments are provided for pilot/operator decision through interactive graphic displays and controls. This shift can be viewed as a change in emphasis from matching man to machine to our developing capability to match the machine to man. Are displays and controls professionals meeting the challenge to exploit this capability at the ultimate interface?

We must make certain that in our hardware hypnosis, in our zeal to provide the best and the most, that we do not denigrate humanity and human interaction, that we do not increase job boredom and reduce motivation and efficienty. Most important, we must not foster within the student a feeling of inadequacy in his ability to cope with problems -- to be in control.

We must capitalize on the computer's capabilities and turn around the thinking of those who find it difficult to cope with inhuman efficiency with which they can neither negotiate nor bargain. Constant and compassionate human interaction can do much to ameliorate the intimidation the student pilot may feel when confronted with a plethora of computers and monitoring equipment.

Above all, we must recognize that more technology is not always better. Considerable unquantifiable human activity requires motivation that is not intrinsic in a machine. And only man himself can insure that motivation.

Psychologists, human factors engineers, and training personnel have great potential to ensure compassionate man-machine interaction. Their design goal should be to take advantage of the behavioral activities of the pilot operators and to circumvent their behavioral limitations in such a manner that motivation and job satisfaction are enhanced. In the end, their greatest challenge is to inject themselves as vital and essential members of the systems engineering team.

REFERENCES

1. Lindahl, Charles E. "Applying Computer Technology to Training Systems." Defense Management Journal, Fourth Quarter, 1980.

2. McCormick, Ernest J. Human Factors in Engineering Psychology and Design (New York: McGraw-Hill Book Co.), 1970.

3. Needham, Richard C., et al. "Flight Simulation in Air-Combat Training." Defense Management Journal, Fourth Quarter, 1980.

4. Perdriel, G., ed. AGARD Conference Proceedings No. 201 on Visual Presentation of Cockpit Information including Special Devices Used for Particular Conditions of Flying (Paris: AGARD), 1976.

5. Roscoe, Stanley N., ed., Aviation Psychology. (Ames, Iowa: Iowa State University Press), 1980.

6. Spooner, A. Michael, et. al. "Visual Simulation in Navy Training." Defense Management Journal. Fourth Quarter 1980.

7. Tomeski, Edward A. and Harold Lazarus. People-oriented Computer Systems (New York: Van Nostrand Reinhold Co.), 1975.

8. Vancott, Harold P. and Robert G. Kinkade. Human Engineering Design (Washington, D. C.: American Institute for Research), 1972.