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AN ERGONOMIC ENGINEERING EVALUATION OF THE SH-2F HELICOPTER COCKPIT

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Anthony Vanaria IV

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DISCLAIMER

This thesis contains technical data collected during an ergonomic engineering evaluation of the SH-2F helicopter cockpit. All opinions and recommendations are the sole opinion of the author, and do not reflect the official position of the Naval Air Test Center, Naval Air Systems Command, the United States Navy or Kaman Aerospace.

ABSTRACT

Within the last two decades, ergonomic research and studies have revealed that until the present, improper emphasis has been placed on the interface between man and machine in the work environment; especially in aviation cockpit design.

Recently, the United States Navy began to procure 48 new Light Airborne Multi Purpose System (LAMPS) Mark I (MK I) SH-2F Sea Sprite helicopters from the Kaman Aerospace Corporation because the new LAMPS MK III SH-60B Sea Hawk was too large to land aboard many of the Navy's older ships. The LAMPS MK I first flew in 1959.

The rationale to retain identical configuration with existing fleet SH-2F aircraft was not sound, in that the SH-2F cockpit is plagued with numerous human factors deficiencies. Thus, it was the purpose of this thesis to conduct an ergonomic engineering evaluation of the SH-2F cockpit and to formulate recommendations for correction of deficiencies.

The ergonomic engineering evaluation of the SH-2F helicopter cockpit consisted of both ground and flight tests. Portions of various military specifications were used during the evaluation, however, human factors design principles learned during thesis research served as the primary basis for thesis construction.

With respect to crew station comfort at night, providing pilots with night vision goggles (NVG) is in the author's opinion, the most significant ergonomic development of this decade. The SH-2F cockpit should be immediately modified for NVG compatibility. In order to help alleviate the scan break down problem encountered during flight in instrument

meteorological conditions, it is recommended that all-attitude indicators similar to those found in most tactical jet aircraft be incorporated immediately in place of the existing attitude indicators. Additionally, numerous other ergonomic design deficiencies requiring correction as well as deficiencies too costly to correct were found.

Similar design principles used during the ergonomic engineering evaluation of the SH-2F cockpit could easily be applied to other older aircraft. Costs incurred in redesigning older aircraft cockpits are justifiable and necessary in that proper ergonomic placement of a poorly located switch may be all that is necessary to prevent an aircraft accident.

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1 INTRODUCTION

1.1 BACKGROUND

Within the last two decades, ergonomic research and studies have revealed that until the present, improper emphasis has been placed on the interface between man and machine in the work environment (reference 1, p. 2). This statement holds especially true in the field of aviation; specifically in cockpit design, where pilots often light-heartedly remark that in older aircraft, the cockpit seems to have been added only as an afterthought.

Recently, the United States Navy began to procure 48 new Light Airborne Multi Purpose System (LAMPS) Mark I (MK I) SH-2F Sea Sprite helicopters from the Kaman Aerospace Corporation. These new SH-2F aircraft are upgrades of the original HU-2, which first flew in 1959. The decision to procure new SH-2F aircraft in addition to newer Sikorsky SH-60B Sea Hawk LAMPS MK III aircraft was made because the SH-60B was too large to land aboard many of the Navy's older ships.

Although the decision to procure new SH-2F helicopters was quite sound, the rationale to retain identical configuration with existing fleet SH-2F aircraft was not sound, in that the SH-2F cockpit is plagued with numerous human factors deficiencies. It seems apparent that most of these human factors deficiencies could be corrected by employing the concepts learned during the aforementioned ergonomic research and studies.

1.2 PURPOSE

Thus, it is the purpose of this thesis to conduct an ergonomic engineering evaluation of the SH-2F cockpit and to formulate recommendations for correction of deficiencies.

1.3 DESCRIPTION OF THE SH-2F HELICOPTER

The SH-2F Sea Sprite is a dual piloted, twin gas turbine powered, single main rotor, single tail rotor, retractable main landing gear, tailwheel configured helicopter designed and manufactured by the Kaman Aerospace Corporation, Bloomfield, Connecticut. The aircraft is designed to operate up to a maximum gross weight of 13,500 lb. The power plant consists of two General Electric T58-GE-8F turboshaft engines, which are rated at 1,350 shaft horse power at sea level, under standard day conditions. The engines provide power to the transmission system which includes a combining gearbox, main gearbox, intermediate gearbox, tail rotor gearbox and associated interconnecting shafts. The combining gearbox transmits engine power to the main gearbox. The main gearbox transmits power to a four bladed, fully-articulated main rotor as well as the tail rotor drive shaft. The intermediate gearbox, which receives and transmits power through the tail rotor drive shaft changes drive shaft direction up to the tail rotor gearbox. The tail rotor gearbox transmits power to a four bladed, fully articulated tail rotor. The aircraft incorporates a single 1,500 psi hydraulic system which provides hydraulic power to the landing gear system, automatic stabilization equipment

(ASE) control actuator, rescue hoist system and windshield wiper system. The flight control system receives inputs through conventional cyclic, collective and directional pedal controls, as well as ASE inputs through the hydraulic ASE actuator and transmits inputs to the main and tail rotors. Main rotor blade pitch is varied by means of a blade servo flap attached to the trailing edge of each blade. The ASE provides airspeed, roll attitude and heading hold. Additionally, barometric altitude hold, radar altitude hold and groundspeed hold features are provided.

The aircraft cockpit was designed to accommodate one pilot and one copilot, providing each with crew seats (right and left respectively) as well as a set of interconnected flight controls, consisting of the previously mentioned cyclic, collective and directional pedals. The cockpit also incorporates the following features: an instrument panel, an overhead console and a center console. The instrument panel incorporates flight instruments which provide each pilot with an instrument flight capability and performance instruments which allow pilots to monitor the status of aircraft systems. The overhead and center consoles provide the locale with which to mount the assorted panels and switches necessary to operate the helicopter.

The SH-2F helicopter is described in detail in reference 2. External views of the aircraft are presented in appendix A, figures 1 through 4.

1.4 SCOPE OF TEST

The ergonomic engineering evaluation of the SH-2F helicopter cockpit consisted of both ground and flight tests. The author, whose anthropometric measurements are presented in appendix B, table I, was fully attired in standard U.S. Navy summer flight gear as listed in appendix B, table II for all tests. Additionally, when discrepancies involving functional reach were discovered, winter flight gear, as listed in appendix B, table II was donned in order to determine if wearing winter flight gear would further exacerbate the discrepancy. Portions of various military specifications were used during the evaluation and shall hereafter be referred to as the Specification. The Specification is presented as appendix B, table III. However, although the Specification was used and quoted, the human factors design principles of references 1, 3, 4, 5, 7, 8, 9, 10 and 11 learned during thesis research served as the primary basis for thesis construction. The author's opinion as a qualified U.S. Navy Test Pilot aided in thesis construction.

1.5 METHOD OF TEST

Entry and egress data were compiled using the ground and cockpit deck for start and finish references as applicable. Cockpit procedures were executed and measurements taken with the pilot seat adjusted vertically in order to situate the author at the design eye position (DEP). DEP calculations are included as appendix C. Normal and emergency checklists (reference 2, pp. III-8-22 through 27 and V-12-1 through 35) were utilized to aid in the evaluation of switches location. Distances, accurate to within 1/4 in, were obtained using a tape measure. Field Of View (FOV) data were taken using a protractor and string. Cockpit temperature and noise level data were obtained from previous Naval Air Test Center flight tests conducted in 1975 and 1983 respectively. Temperature and noise level data are considered current since the recently procured aircraft are identical to those tested in 1975 and 1983. During all phases of the evaluation, except ground taxi, takeoffs and landings and certain emergencies; which require a locked shoulder harness, the pilot was free to position himself within the constraints of a locked lap belt and an unlocked shoulder harness.

2 RESULTS AND DISCUSSION

2.1 COCKPIT ENTRY AND EGRESS

2.1.1 Entry

The cockpit was evaluated for ease and safety of entry. Only the method with which to gain entry to the pilot seat will be discussed since procedures for accessing the pilot (right) and copilot (left) seats are mirror images of one another. Cockpit entry proved to be much more awkward than appearances indicated. First, one was required to access the kick-in step located 30 1/2 in above the ground as shown in appendix A, figure 5 with the left foot. The location of the kick-in step, far beyond comfortable reach as well as the small step size not accommodating the entire ball of the left foot made balancing precarious. The second phase of entering the cockpit was to step up to the cockpit deck with the right foot, and simultaneously rotate the body 90 deg to the right while lifting the left leg over the pilot seat, then lowering to a seated position. During this second phase, the author experienced a temporary loss of balance, nearly falling. Cockpit entry was judged neither easy nor safe. The designers of the kick-in step apparently did not consider the step's use ". . . in a dynamic setting" (reference 3, p. 517). In order to improve balance during entry, it is recommended that a boarding ladder, similar to those found on most tactical jet aircraft and depicted in appendix A, figure 6, be incorporated in lieu of the kick-in step. A boarding ladder would allow for comfortable reach and permit safe balance while rotating the body. Since boarding ladders are telescopic, one would easily fit into the space now occupied by the kick-in step as well as utilize the same airframe structural member for support of pilot body weight as does the current kick-in step. The Specification paragraph 5.14.3 requires that the aircraft be supplied with "suitable" hand and footholds where necessary; the author determined the kick-in step to be unsuitable for safe entry.

2.1.2 Egress

Ease and safety of egress from the cockpit was also evaluated. Only the method with which to egress from the pilot seat will be discussed since procedures for egressing from the pilot and copilot seats are mirror images of one another. As was the case with entry, egress proved precarious. The pilot was required to lift himself to a crouching position and then simultaneously support and balance his weight on the right foot, rotate his body 90 deg to the left and place his left foot in the kick-in step. Once again, the difficulty encountered was in accessing the kick-in step, shown in appendix A, figure 5. As the kick-in step was not in the field-of-view, the pilot was required to blindly feel for the kick-in step with his left foot, which proved quite difficult. Once the left foot was in the kick-in step, the same problem of safe balance as had been experienced during entry was found. Cockpit egress was similarly judged as unsafe and difficult. As before, the designers of the kick-in step apparently did not consider the step's use ". . . in a dynamic setting" (reference 3, p. 517). The same recommendation made for entry applies to egress; a boarding ladder, similar to those found on most tactical jet aircraft and depicted in appendix A, figure 6, should be incorporated in lieu of the kick-in step. A boarding ladder would be visible; not requiring blind access and would permit safe balance. Once again, the Specification paragraph 5.14.3 requires that the aircraft be supplied with "suitable" hand and footholds where necessary; the kick-in step is unsuitable for safe egress.

2.2 CREW STATION COMFORT

2.2.1 Seats

The pilot and copilot seats were evaluated for anthropometric accommodation and overall comfort. Summary data from the 1964 U.S. Navy and Marine Corps anthropometric survey are presented as appendix B, table IV. The pilot seat was adjustable vertically from 4 3/4 to 11 1/4 in above the cockpit deck; accommodating the sitting eye height of the first through ninety-ninth percentile male naval aviators. However, the following recommended design features (reference 4, p. 58) were not provided: seat horizontal adjustment (pilot and copilot seats), seat vertical adjustment (copilot seat) and seatback support for the lumbar region (pilot and copilot seats). Designing for varying anthropometry was obviously not considered in the construction of SH-2F seats. Qualitatively, overall seat comfort levels were deemed poor and fatiguing during 1.5 hour flights in each, with the pilot seat being slightly more tolerable than the copilot seat due to its provision for vertical adjustment. Seats that are both vertically and horizontally adjustable and which incorporate lumbar supports would accommodate pilots of varying anthropometry, significantly increasing crew comfort and staying the onset of fatigue. Vertically and horizontally adjustable seats with lumbar supports suitable for rotary wing aircraft are readily available and should be installed. Installation would require only minor redrilling of holes in the cockpit deck in order to mount the seats. The Specification paragraph 5.14.2 requires seats to incorporate "vertical and horizontal adjustments sufficient to accommodate . . . fifth and ninety-fifth percentile" and also provide "supporting framework for the body relative to the activities that must be performed." The current seats obviously do not meet these requirements.

2.2.2 Temperature and Noise Levels

Although separate entities, in the SH-2F cockpit, temperature and noise levels are directly related and are accordingly discussed together. Temperature and noise level data are provided in appendix B, tables V and VI respectively. Temperatures, recorded with cockpit sliding doors open, varied from ambient in a hover to seven deg F above ambient at maximum continuous power cruise. The helicopter incorporates a heater to warm the cockpit for cold weather operations. However, the helicopter is not equipped with an air conditioner for hot weather operations and summer time comfort is therefore dependent upon ambient conditions. Generally, with the sliding doors open and temperatures moderate, cockpit temperature levels were relatively comfortable.

However, having the sliding cockpit doors open creates a problem with noise levels. In general, "continuous long-term occupational exposure to noises above 85-90 dbA creates a risk of permanent hearing loss" (reference 4, p. 87). The cockpit noise level values of appendix B, table VI, which range from 78.7 dbA on the ground with engines at idle to 83.4 dbA at maximum continuous power cruise, are predictions for those levels pilots will encounter while wearing the current SPH-3C sound attenuation helmet. These values are, however, computer generated predictions. Attired with an SPH-3C helmet for sound attenuation and further protected with earplugs underneath his helmet, the author's ears actually hurt for more than an hour after completing a 1.5 hour flight with the sliding doors open to obtain a comfortable cockpit temperature. Thus, it is believed that the computer generated attenuated noise level data is inaccurate and that actual noise levels are much higher than predicted.

To obtain both comfortable temperature and noise levels, the following should be implemented: the aircraft should be equipped with an air conditioner and all flights should be conducted with the sliding doors closed. The prudent choice for an air conditioner is one driven by engine bleed air vice one powered electrically since the SH-2F engines provide excess power available above that which can be utilized by the transmission system. Thus, an air conditioner could be incorporated without affecting aircraft performance. Additionally, soundproofing material should be added to the cockpit overhead, doors and the aircraft cabin to further reduce noise levels.

2.2.3 Field of View

Field of View (FOV) was quantitatively measured on the ground with rotors static and qualitatively evaluated in flight. Appendix A, figures 7 to 11 are photographs from a camera positioned at the DEP depicting FOV as seen from the pilot seat. Forward FOV was obstructed from 30 deg below the horizon in level flight by the instrument panel and by numerous windshield supports. FOV beyond 110 deg left and 125 deg right was totally blocked, except for the small aft FOV provided by externally mounted mirrors. During operations which simulated landing on a ship with a small deck, the pilot repeatedly lost sight of line-up lines due to forward FOV being obstructed by the instrument panel and was required to rely on peripheral cues to control drift, which is a difficult task. FOV was thus found as qualitatively unacceptable for small deck operations. In the author's opinion, during a small deck landing, a strong potential exists for undetected forward drift and a main rotor blade strike on the hangar with potential for flight deck personnel injuries or fatalities. SH-2F main rotor blade strikes with shipboard hangars have occured in the past. However, the resultant mishap investigation reports are not quoted or referenced here in that investigation results are proprietary. In order to make the FOV acceptable for small deck operations, only the forward FOV need be improved, which would prevent situations of undetected drift as described above from occurring. A design change of lowering the instrument panel 1 1/4 in would provide forward FOV up to 40 deg below the horizon and is recommended for incorporation. FOV at 40 deg below the horizon would be sufficient to provide the pilot a continuous view of line-up lines. Ample space with which to lower the instrument panel 1 1/4 in exists and would accommodate pilot legs and avionics. Although paragraph 8.1 of the Specification requires that forward FOV of 50 deg below the horizon be provided, FOV of 40 deg below the horizon will provide sufficient FOV for operations on ships with small decks.

2.2.4 Interior Lighting

With respect to crew station comfort at night, providing pilots with night vision goggles (NVG) is in the author's opinion, the most significant ergonomic development of this decade. Without (NVG), pilots must utilize cockpit instruments only for reference, which, in missions of long duration, is both demanding and fatiguing, resulting in numerous aircraft mishaps. NVG allow pilots to see out of the cockpit in near total darkness by amplifying ambient light in the red and near infrared wavelengths (reference 5, p. 1). Current aviators night vision imaging system 6 (AN/AVS-6) NVG add only an approximate 1.1 lb of balanced weight to helmets (reference 6, p. 1-22). The author, having flown at night in other aircraft with NVG, can personally attest to the unparalleled comfort which NVG provide. However, as in the case of the SH-2F, should cockpit interior lighting emit energy in the red or near infrared regions, non compatibility with NVG would occur. Yet, some type of lighting must illuminate cockpit instruments and indicators.

Since ambient light which falls in the range 600-900 nanometers is used by NVG to produce a view of the terrain, any cockpit interior light which emits energy above approximately 525 nanometers (green light) is a problem, causing a protective shut down of the NVG (reference 7, p. III-24). Possible solutions to aircraft non NVG compatibility are to either provide light that is NVG compatible or filter light to make it NVG compatible (reference 7, p. III-25). Although the former solution is by far the most desirable since it would provide for instruments specifically designed to be NVG compatible, the prudent alternative is actually a combination of both. First, provide a series of green flood lights underneath and along the length of the instrument panel glare shield as well as along the length of the overhead and center consoles. This would allow all existing red lights to be turned off whenever NVG flight is desired and still permit pilots to view instruments and panels. Next, filter caution panel lights with a removable green filter, which would allow caution lights to be visible during both day and night flight (reference 8, p. III-25).

The execution of the previous two recommendations would draw upon items which are readily available, saving costs in both development and procurement. More importantly, safety in the execution of night operations would be greatly enhanced and night crew comfort would be optimized. Cockpits should be immediately modified for NVG compatibility.

2.3 INSTRUMENT PANEL

2.3.1 Attitude Indicators

The attitude indicators were evaluated for effectiveness. The two attitude indicators, an example of which is shown in appendix A, figure 12 were located on the instrument panel directly in front of each pilot. The attitude indicators provide pilots with a pictorial presentation of aircraft pitch and roll attitude and are the primary reference instruments by which flight in instrument meteorological conditions (IMC) is enabled. During instrument flight, pilots reference the attitude indicators and alternately scan other flight instruments to determine aircraft spatial orientation. Although sounding easy in theory, maintaining a continuous instrument scan is a tiresome struggle requiring constant and total concentration of the pilots. A break down in scan during IMC can induce vertigo and on occasion, in the past has ultimately resulted in loss of aircraft and crew due to ground impact (reference 9, pp. 221-222). Thus, attitude indicators are not totally effective for IMC flight. An all-attitude indicator as shown in appendix A, figure 13 not only presents pitch and roll information, but also displays heading information and additionally incorporates a turn-and-slip indicator. With all-attitude indicators, a quick glance in one central location would provide pilots essential flight information which at present requires scanning three separate instruments (reference 9, p. 227). Thus, all-attitude indicators are more effective for IMC flight than are standard attitude indicators. All-attitude indicators dimensionally occupy the same space as do the present attitude indicators; only minor rewiring and no structural modifications would be required to the instrument panel in order to install all-attitude indicators. Additionally, by incorporating all-attitude indicators, additional space on the instrument panel will be created in that the existing turn-and-slip indicators could be removed. It is recommended that all-attitude indicators be incorporated immediately.

2.3.2 Warning, Caution and Advisory Lights

The warning, caution and advisory lights were evaluated for location and visual cuing. The warning and advisory lights, consisting of bleed air pressure, thirty minute fuel, radar altimeter warning, ASE off and inflight refuel lights were found by the author to be at seemingly random locations on the instrument panel as shown in appendix A, figures 14 and 15. The caution panel, consisting of 24 lights, was located on the overhead console and is shown in appendix A, figure 16. All warning, caution and advisory lights were amber colored; thus quick visual discrimination between either the severity of various emergencies (warning and caution lights) or the status of a normal system (advisory lights) was not possible. In fact, after simulating cockpit emergency procedures of reference 2, no logic was found behind the design criteria used to differentiate between which emergencies warranted a warning light and which emergencies warranted a caution light. It is recommended that the existing warning lights, advisory lights and caution panel, be replaced with one central warning, caution and advisory panel, color coded by red, amber and green lights respectively. Similar color coding is required for helicopters by Federal Aviation Regulations Part 27 (reference 10, pp. 37-38). The only warning lights should consist of five new lights: left engine fire, left engine out, right engine fire, right engine out and low rotor RPM. These five new lights should be red warning lights in that the emergencies which the new lights represent require immediate action by the pilot. The existing warning lights should become and be combined with the existing caution lights, the illumination of which would indicate that emergency pilot action, although not immediate, is required. The existing advisory lights should remain advisory lights. Incorporating the new 34 total warning, caution and advisory lights into one panel requires minor structural and wiring rework to the instrument panel. Moving the landing gear indicators four inches to the left, lowering the combining gear box and transmission oil pressure gauges one inch and deleting the existing master caution light would provide space for 36 lights (six rows of six lights; a 2 1/2 in X 6 1/2 in panel) as shown in appendix A, figure 17. Additionally, space on the panel for two spare lights would then exist, allowing room for future growth. Lastly, new master warning lights should be placed directly in front of each pilot, illuminating whenever a warning light illuminates, in order to cue pilot attention to the warning, caution and advisory panel. Ample space in the proposed locations exists for the addition of new master warning lights. The Specification paragraph 5.2.1.4 requires that ". . . displays necessary to support an operator activity or sequence of activities, shall be grouped together." The warning, caution and advisory lights were not grouped together.

2.3.3 Triple Tachometer

Navy helicopters are dual piloted aircraft and should accordingly provide pilots the instrumentation necessary to conduct flight operations from either seat. However, in the SH-2F, the copilot station is not so equipped. The SH-2F cockpit provides only the pilot with a triple tachometer; a gauge with three indicating needles which simultaneously presents the free power turbine speed of both engines as well as the main rotor RPM (NR) to the pilot.

Maintaining proper NR in a helicopter is critical. Should NR decay below a certain value which is dependent upon ambient and flight conditions, an unrecoverable loss of lift would result. Accurately reading the pilot station triple tachometer from the copilot seat was not possible, even when leaning far right, at the full extent of an unlocked shoulder harness; a very awkward position. Thus, the copilot station should be equipped with a triple tachometer. Equipping the copilot station with a triple tachometer appears easy, once again requiring minor structural and wiring modifications to the instrument panel. The proposed triple tachometer installation, shown in appendix A, figure 18, would mirror that of the pilot station by moving the compass correction card and bearing distance heading indicator (BDHI) switch to unoccupied space and lowering the copilot BDHI and airspeed indicator. The Specification, paragraph 5.2.1.4 requires that "displays shall be located and designed so that they may be read to the degree of accuracy required . . .without requiring the operator to assume an uncomfortable, awkward or unsafe position." As previously discussed, accurately reading the pilot triple tachometer from the copilot seat was not possible.

2.3.4 Utility Hydraulic Gauge

The utility hydraulic gauge was evaluated for optimum placement on the instrument panel. The existing and proposed locations of the utility hydraulic gauge are presented in appendix A, figure 19. The utility hydraulic gauge displays the operating pressure of the utility hydraulic system which powers essential aircraft systems including main landing gear and windshield wipers. The aircraft should be equipped with a utility hydraulic gauge which both pilots can monitor. As was the case with the pilot triple tachometer, reading the utility hydraulic gauge from the copilot seat was not possible, even by leaning far right, at the full extent of an unlocked shoulder harness. Accordingly, the existing placement of the utility hydraulic gauge was deemed as not optimal. The placement proposed moves the utility hydraulic gauge to the same location as the engine and transmission performance instruments, thereby creating a functional group of all aircraft performance instruments. Drilling a hole in and rerouting wires to the new location would be required in order to relocate the gauge; work which appears very minimal. The Specification, paragraph 5.2.1.4 requires that "displays shall be located and designed so that they may be read to the degree of accuracy required . . .without requiring the operator to assume an uncomfortable, awkward or unsafe position." Reading the utility hydraulic gauge from the copilot seat was not possible.

2.3.5 Miscellaneous

The previous four paragraphs discussed the minimum ergonomic engineering changes which the author believes the SH-2F cockpit instrument panel requires. However, there exist two other changes of a less critical nature which would improve the layout of the instrument panel. These changes include:

1. relocating the copilot landing light switch from the instrument panel to the copilot collective where light switches are usually located as

shown in appendix A, figures 20 and 21 respectively (requires rewiring and structural work on the copilot collective);

2. relocating the SET ALT HOLD panel from the instrument panel to the center console, near the vicinity of other ASE controls as shown in appendix A, figures 22 and 23 respectively (requires lengthening of wiring to reach the center console and minor structural work).

Relocating the copilot landing light switch to the copilot collective and the SET ALT HOLD panel to the vicinity of other ASE controls would follow the ergonomic design principle of functional grouping by which "controls with related functions are placed together" (reference 1, p. 17). Once again, these two changes are not critical in that the aircraft can safely and effectively perform its mission without their incorporation. Thus, it is proposed that the copilot landing light switch and SET ALT HOLD switch be relocated only after the recommendations of the preceding four paragraphs are incorporated.

2.4 OVERHEAD CONSOLE

2.4.1 Fuel Control Selector Switches

The fuel control selector switches, shown in appendix A, figure 24 are toggle switches with normal and emergency positions. With either fuel control selector switch in the normal position, the respective RPM switch, shown in appendix A, figure 25 may be used for fine adjustment of main rotor RPM, with the engine operating in the governed range. However, with either fuel control switch in the emergency position, the RPM switch directly controls the respective engine emergency fuel control actuator, acting as a manual throttle. A fuel control selector switch would be selected to the emergency position if a partial power loss to an engine occurred (reference 2, p. V-12-1). With a partial power loss, should a delay in the selection of emergency occur, an unrecoverable decay in NR would quite possibly follow. While simulating emergency procedures from the pilot seat, the location on the overhead console of the fuel control selector switches was evaluated. With shoulder harness locked, as it would be for an actual emergency, both switches were 3 3/4 in beyond the functional reach of a fortieth percentile naval aviator (appendix B, table I), which made rapid selection of emergency impossible. The data of appendix B, table IV shows that with a locked shoulder harness, the fuel control selector switches would actually be beyond the reach of all aviators below ninety-eighth percentile. Fundamental ergonomic engineering requires switches as important as are the fuel control selector switches to "be positioned in the best locations for rapid and easy use" (reference 11, p. 394). Although moderate structural rework and rewiring would be necessary, the fuel control selector switches should be broken up into two sets of identical switches and be repositioned to both pilot and copilot collectives with locations as shown in appendix A, figures 26 and 27. The proposed installation would require the enlargement of the faces of both collectives, for which free space exists. Also, it is further proposed that the toggle switches then be guarded with red covers in order to prevent accidental actuation. Critical time would be saved in the selection of a fuel control selector switch to emergency were the recommendation implemented. The Specification, paragraph 5.4.1.3 requires "the most important and frequently used controls shall have the most favorable position with respect to reaching and grasping." Obviously, the current position of the fuel control selector switches did not meet Specification criteria.

2.4.2 Emergency Panel

In a like manner as were the fuel control selector switches, the emergency panel was evaluated for optimum ergonomic placement within the cockpit while simulating emergency procedures from the pilot seat. The emergency panel, shown in appendix A, figure 28 possesses three toggle switches, jettison magnetic anomaly detector (MAD) vehicle, jettison stores and jettison fuel which would be used in order to jettison the MAD, external stores (auxiliary fuel tanks or torpedos) or internal fuel respectively. Jettison of the MAD is required when the reeling machine fails and the towed vehicle is deployed and unrecoverable. Accessing the jettison MAD vehicle switch posed no problem since execution of unrecoverable MAD procedures do not require a locked shoulder harness. Jettison of external stores and, or internal fuel is required in the event of engine failure in order to reduce aircraft gross weight. With an engine failure, should a delay in the reduction of aircraft gross weight occur, an unrecoverable decay in NR would likely follow. As would be required during a single engine failure, with a locked shoulder harness, the author (a fortieth percentile aviator) found the jettison stores and jettison fuel switches to be at the very limit of his functional reach. After donning winter flight gear, with shoulder harness locked, the author could access the jettison stores and jettison fuel switches only by straining forward against the limits of the shoulder harness. Accordingly, the jettison stores and jettison fuel switches were judged to be beyond the reach of all aviators below fortieth percentile. Sound ergonomic design requires a panel with switches as important as those found on the emergency panel "be positioned in the best locations for rapid and easy use" (reference 11, p. 394). Although moderate rewiring is required, the emergency panel should be moved to the center console. Panel space on the center console would be created by the removal of the pilot communication controls and MAD control panels (refer to paragraphs 2.5.2 and 2.5.3 respectively). The proposed relocation is provided in appendix A, figure 29. No structural modifications to the center console would be required in order to incorporate the emergency panel. In the event of an engine failure, critical time in the reduction of aircraft gross weight would be saved if the recommendation for relocating the emergency panel is implemented. The Specification, paragraph 5.4.1.3 requires "the most important and frequently used controls shall have the most favorable position with respect to reaching and grasping." The current location of the emergency panel does not meet this criteria.

2.4.3 Miscellaneous

The previous two paragraphs document the only two proposed design changes of necessity which the overhead console requires. However, an overall examination of the overhead console reveals numerous deficiencies and truly brings to light the fact that the SH-2F cockpit was designed without benefit of ergonomic expertise. The following summarizes the overall examination of the overhead console:

1. There exist two panels, the first being the miscellaneous controls panel and the second being the heat and miscellaneous controls panel, shown in appendix A, figures 30 and 31 respectively. Inspection of the two panels reveals a hodgepodge of switches which appear to have been placed without any ergonomic design considerations. Locating individual switches on these two panels was found to be both untimely and frustrating. The heating switches should have been incorporated on a separate heating panel. The windshield washer switch should have been placed next to the windshield wiper control. The remote attitude indicator (RAI) switch, which allows either pilot's attitude gyro to receive reference information from the other pilot's vertical gyro (used in the event of a vertical gyro failure) should have been broken up into two similar switches located directly beneath both attitude gyros. The lateral coupler and hydraulic actuator switches should have been incorporated on a separate flight controls panel. The two suit vent switches should have been deleted in all new procurement aircraft since naval aviators no longer use ventilated wet suits. The aux fuel tank switches should have been incorporated on a separate panel labeled aux fuel tanks. The proposed redesign is illustrated in appendix A, figures 32 and 33.

2. The starting panel, shown in appendix A, figure 34 should only consist of the starter and ignition system test switch and the fuel pumps switch. The remaining switches should have been incorporated on a new electrical panel, possessing the battery, generator and power monitor switches. The proposed redesign is illustrated in appendix A, figure 35.

The above mentioned deficiencies are numerous and appear too costly to correct on recently procured SH-2F aircraft. However, the presence of deficiencies such as these demonstrate a general lack of expertise in ergonomic design principles, and further support the conclusion that with newly procured aircraft, the rationale to retain identical configuration with existing fleet SH-2F aircraft was not sound.

2.5 CENTER CONSOLE

2.5.1 Engine Start System

The engine start system was evaluated for functional operation. A starter switch is incorporated on each engine condition lever (ECL) as shown in appendix A, figure 36. The starter switch controls a relay which supplies electrical power to the engine starter motor and a relay which supplies electrical power to the engine ignitor plugs (reference 2, p. 1-2-9). During engine start, in addition to ECL advancement to the idle-start position at 19% engine gas generator speed (NG), the pilot is required to continuously depress the starter switch until NG reaches 46% (reference 2, p. III-8-23). Inadvertent release of the starter switch prior to NG reaching 46% may result in engine overtemperature with the probability of overtemperature increasing the lower the NG is upon starter switch release. Although rare, inadvertent release and subsequent overtemperature have occurred in the past (reference 12). Redesign of the engine start system so that momentary starter switch actuation would energize the relays and an NG of 46% would automatically deenergize the relays would eliminate the inadvertent starter switch release problem. Additionally, the start system could be further modified so that a second momentary actuation of the starter switch would deenergize both relays, allowing pilots to abort starts if necessary. Other aircraft are equipped with engine start systems which require only momentary starter switch actuation; for example, the SH-3D/H Sea King (reference 13, p.1-23). Thus, the technology with which to modify the SH-2F engine start system is readily available. The SH-2F engine start system should eventually be modified as recommended.

2.5.2 Pilot Communication Controls

The pilot communication control panels, consisting of radio selector and intercommunication system (ICS) panels were evaluated for ergonomic placement. Unlike the copilot communication control panels, which were located on the overhead console, the pilot panels were located on the center console as shown in appendix A, figure 37. The present placement of the two pilot communication panels, 120 deg left and 60 deg below the DEP was deemed to be inappropriate. Communication control switches are among the most frequently utilized switches in any cockpit. While flying as the pilot, one was frequently required to break his outside or instrument scan, turn his head 120 deg left and look down 60 deg to locate the communication panels in order to increase or decrease radio volume levels and select or deselect radios. Sound ergonomic design dictates that the most frequently used items be placed in "preferred locations. . . relegating to other locations the items which are less frequently used" (reference 11, p. 395). The pilot communication control panels should be relocated to the overhead console position shown in appendix A, figure 38. The proposed location would permit the pilot to maintain an outside or instrument scan while promoting quick and easy access to a frequently used control, thereby optimizing ergonomic placement. The proposed relocation would also form a functional group with the copilot communication control panels by placing all the communications switches in the same area. Although moderate work in the rerouting of radio wires to the overhead console would be required, no structural modifications are needed since the communications panels will exactly fit into the overhead console. Space would be made by the relocation of the caution panel, fuel control selector switches and emergency panel (refer to paragraphs 2.3.2, 2.4.1 and 2.4.2 respectively). The Specification, paragraph 5.4.1.3 requires "the most important and frequently used controls shall have the most favorable position with respect to reaching and grasping." Obviously, the current position of the pilot communication control panels did not meet Specification criteria.

2.5.3 Magnetic Anomaly Detector Control Panel

The magnetic anomaly detector (MAD) control panel was installed on the center console and is shown in appendix A, figure 39. The MAD control panel provides electrical power to a reeling machine located externally on the aircraft's starboard side. The reeling machine provides the means with which to deploy and recover the MAD towed body, shown in appendix A, figure 40. The MAD towed body is a device attached to a 200 ft cable, used in order to search for submarines. During antisubmarine warfare (ASW) missions in the SH-2F, an enlisted naval aircrewman performs all associated MAD functions except deployment and recovery. The apparent question which arises is why the aircrewman was not also given the responsibility for MAD deployment and recovery; a question for which the author can find no explanation. In other helicopters, an aircrewman performs all MAD functions with the MAD control panel being located at the aircrewman station. The MAD control panel should be relocated to the aircrew station. Relocation requires wires to be rerouted, but does not require structural modifications since the dimensions of the MAD control panel would fit perfectly into any one of several unoccupied panel spaces in the aircrewman station. "Close attention to a given task will largely exclude attention to others" (reference 9, p. 317). Thus, the removal from the cockpit of the MAD control panel, which equates to one less task to be performed in the cockpit, is a significant design improvement.

2.5.4 Control Display Unit

Most recently designed and procured aircraft incorporate a control display unit (CDU) of one form or another. A CDU as installed in the SH-60F helicopter is shown as appendix A, figure 41. A CDU is a centralized panel which can take the place of any or all individual control panels. CDUs incorporate individual push buttons which, when selected, display unique menus. In general, CDU menus mirror the functions which would be provided on individual control panels. Pilots then gain control of the various aircraft systems by pressing line function keys next to the desired item on a displayed menu. For example, the aircraft's tactical air navigation (TACAN) control panel could be replaced with CDU driven menus as follows:

1. The CDU incorporates a push button labeled NAV (for navigation).

2. Upon pressing the NAV push button, the acronym TACAN is displayed next to one of the line function keys (in addition to other possible navigation functions being displayed next to the remaining line function keys).

3. Upon pressing the line function key next to the acronym TACAN, the acronyms REC (for receive), T/R (for transmit and receive), A/A REC (for air-to-air receive) and A/A T/R (for air-to-air transmit and receive) are each displayed next to individual line function keys, representing individual modes available.

4. The desired mode of operation for the TACAN would then be obtained by pressing the applicable line function key.

However, not all control panels should be incorporated into a CDU. Specifically, any system which pilots require immediate access to should not be part of a CDU. For example, in the SH-60F aircraft, increasing and decreasing ICS and radio volumes is CDU driven, requiring three steps in order to gain access to volume control (reference 14, pp VII-15-3 through 8). Quite often in the SH-60F, should radio reception be too weak, by the time volume is increased, the transmission is over. ICS and radio control functions should remain on panels separate from a CDU.

With respect to the SH-2F, the following systems and related panels should eventually be incorporated into a CDU: transponder, On Top Position Indicator (OTPI), TACAN, gyro compass and armament controls. Incorporation could be made using existing CDU panels such as that installed in the SH-60F but would require changing push button labels, rewriting software programs and major rewiring. The proposed installation would be time consuming and would best be made during each individual aircraft's first rework. Since recently procured SH-2F aircraft will likely follow suit with other naval helicopters, a 30 year or greater service life is not out of question. CDU incorporation would further provide the SH-2F a growth capability for the addition of new systems which may be invented over the aircraft's service life, allowing the SH-2F to better perform its mission into the next century.

3 SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND IMPLICATIONS

3.1 SUMMARY

Although the decision to procure new SH-2F helicopters was quite sound, the rationale to retain identical configuration with existing fleet SH-2F aircraft was not sound, in that the SH-2F cockpit is plagued with numerous human factors deficiencies. It has been demonstrated that many of these human factors deficiencies could be corrected by employing sound ergonomic engineering design principles.

3.2 CONCLUSIONS

3.2.1 Cockpit Entry and Egress

3.2.1.1 Entry

A. Cockpit entry was judged neither easy or safe (refer to paragraph 2.1.1).

B. The author determined the kick-in step to be unsuitable for safe entry (refer to paragraph 2.1.1).

3.2.1.2 Egress

A. Cockpit egress was judged neither easy or safe (refer to paragraph 2.1.2).

B. The author determined the kick-in step to be unsuitable for safe egress (refer to paragraph 2.1.2).

3.2.2 Crew Station Comfort

3.2.2.1 Seats

A. Overall seat comfort levels were deemed poor and fatiguing (refer to paragraph 2.2.1).

3.2.2.2 Temperature and Noise Levels

A. With the sliding doors open and temperatures moderate, cockpit temperature levels are relatively comfortable (refer to paragraph 2.2.2).

B. Having the sliding cockpit doors open creates a problem with noise levels (refer to paragraph 2.2.2).

C. The computer generated attenuated noise level data is inaccurate and actual noise levels are much higher than predicted (refer to paragraph 2.2.2).

D. The prudent choice for an air conditioner is one driven by engine bleed air vice one powered electrically (refer to paragraph 2.2.2).

E. An air conditioner could be incorporated without affecting aircraft performance (refer to paragraph 2.2.2).

3.2.2.3 Field of View

A. FOV was qualitatively unacceptable for small deck operations (refer to paragraph 2.2.3).

B. In order to make the FOV acceptable for small deck operations, only the forward FOV need be improved (refer to paragraph 2.2.3).

3.2.2.4 Interior Lighting

A. Safety in the execution of night operations would be greatly enhanced and night crew comfort would be optimized were cockpits modified for NVG compatibility (refer to paragraph 2.2.4).

3.2.3 Instrument Panel

3.2.3.1 Attitude Indicators

A. Attitude indicators are not totally effective for IMC flight (refer to paragraph 2.3.1).

3.2.3.2 Warning, Caution and Advisory Lights

A. Quick visual discrimination between either the severity of various emergencies (warning and caution lights) or the status of a normal system (advisory lights) was not possible (refer to paragraph 2.3.2).

B. No logic was found behind the design criteria used to differentiate between which emergencies warranted a warning light and which emergencies warranted a caution light (refer to paragraph 2.3.2).

3.2.3.3 Triple Tachometer

A. The SH-2F cockpit does not provide pilots the instrumentation necessary to conduct flight operations from either seat (refer to paragraph 2.3.3).

3.2.3.4 Utility Hydraulic Gauge

A. The existing placement of the utility hydraulic gauge was deemed as not optimal (refer to paragraph 2.3.4).

3.2.3.5 Miscellaneous

A. Relocating the copilot landing light switch to the copilot collective and the SET ALT HOLD panel to the vicinity of other ASE controls would follow the ergonomic design principle of functional grouping (refer to paragraph 2.3.5).

3.2.4 Overhead Console

3.2.4.1 Fuel Control Selector Switches

A. Fundamental ergonomic engineering requires switches as important as are the fuel control selector switches to be positioned in the best locations for rapid and easy use (refer to paragraph 2.4.1).

3.2.4.2 Emergency Panel

A. Sound ergonomic design requires a panel with switches as important as those found on the emergency panel to be positioned in the best locations for rapid and easy use (refer to paragraph 2.4.2).

3.2.4.3 Miscellaneous

A. Inspection of the miscellaneous controls as well as the heat and miscellaneous controls panels reveals a hodgepodge of switches which appear to have been placed without any ergonomic design considerations (refer to paragraph 2.4.3).

3.2.5 Center Console

3.2.5.1 Engine Start System

A. Redesign of the engine start system so that momentary starter switch actuation would energize the relays and an NG of 46% would automatically deenergize the relays would eliminate the inadvertent starter switch release problem (refer to paragraph 2.5.1).

B. The technology with which to modify the SH-2F engine start system is readily available (refer to paragraph 2.5.1).

3.2.5.2 Pilot Communication Controls

A. The present placement of the two pilot communication panels, 120 deg left and 60 deg below the DEP was deemed to be inappropriate (refer to paragraph 2.5.2).

3.2.5.3 Magnetic Anomaly Detector Control Panel

A. The removal from the cockpit of the MAD control panel, which equates to one less duty to be performed in the cockpit, is a significant design improvement (refer to paragraph 2.5.3).

3.2.5.4 Control Display Unit

A. Not all control panels should be incorporated into a CDU. Specifically, any system which pilots require immediate access to should not be part of a CDU (refer to paragraph 2.5.4).

B. Since recently procured SH-2F aircraft will likely follow suit with other naval helicopters, a 30 year or greater service life is not out of the question (refer to paragraph 2.5.4).

C. CDU incorporation would provide the SH-2F a growth capability for the addition of new systems which may be invented over the aircraft's service life, allowing the SH-2F to better perform its mission into the next century (refer to paragraph 2.5.4).

3.3 RECOMMENDATIONS

3.3.1 Cockpit Entry and Egress

3.3.1.1 Entry

A. A boarding ladder, similar to those found on most tactical jet aircraft should be incorporated in lieu of the kick-in step (refer to paragraph 2.1.1).

3.3.1.2 Egress

A. A boarding ladder, similar to those found on most tactical jet aircraft should be incorporated in lieu of the kick-in step (refer to paragraph 2.1.2).

3.3.2 Crew Station Comfort

3.3.2.1 Seats

A. Vertically and horizontally adjustable seats with lumbar supports suitable for rotary wing aircraft are readily available and should be installed (refer to paragraph 2.2.1).

B. Seats that are both vertically and horizontally adjustable and which incorporate lumbar supports would accommodate pilots of varying anthropometry, significantly increasing crew comfort and staying the onset of fatigue (refer to paragraph 2.2.1).

3.3.2.2 Temperature and Noise Levels

A. To obtain both comfortable temperature and noise levels, the aircraft should be equipped with an air conditioner and all flights should be conducted with the sliding doors closed (refer to paragraph 2.2.2).

B. Soundproofing material should be added to the cockpit overhead, doors and the aircraft cabin to further reduce noise levels (refer to paragraph 2.2.2).

3.3.2.3 Field of View

A. A design change of lowering the instrument panel 1 1/4 in would provide forward FOV up to 40 deg below the horizon and is recommended for incorporation (refer to paragraph 2.2.3).

3.3.2.4 Interior Lighting

A. Provide a series of green flood lights underneath and along the length of the instrument panel glare shield as well as along the length of the overhead and center consoles (refer to paragraph 2.2.4).

B. Filter caution panel lights with a removable green filter, which would allow caution lights to be visible during both day and night flight (refer to paragraph 2.2.4).

C. Cockpits should be immediately modified for NVG compatibility (refer to paragraph 2.2.4).

3.3.3 Instrument Panel

3.3.3.1 Attitude Indicators

A. All-attitude indicators should be incorporated immediately (refer to paragraph 2.3.1).

B. All-attitude indicators are more effective for IMC flight than are standard attitude indicators (refer to paragraph 2.3.1).

3.3.3.2 Warning, Caution and Advisory Lights

A. The existing warning lights, advisory lights and caution panel, should be replaced with one central warning, caution and advisory panel, color coded by red, amber and green lights respectively (refer to paragraph 2.3.2).

B. The only warning lights should consist of five new lights: left engine fire, left engine out, right engine fire, right engine out and low rotor RPM (refer to paragraph 2.3.2).

C. The existing warning lights should become and be combined with the existing caution lights (refer to paragraph 2.3.2).

D. The existing advisory lights should remain advisory lights (refer to paragraph 2.3.2)

E. New master warning lights should be placed directly in front of each pilot, illuminating whenever a warning light illuminates (refer to paragraph 2.3.2).

3.3.3.3 Triple Tachometer

A. The copilot station should be equipped with a triple tachometer (refer to paragraph 2.3.3).

3.3.3.4 Utility Hydraulic Gauge

A. The aircraft should be equipped with a utility hydraulic gauge which both pilots can monitor (refer to paragraph 2.3.4).

3.3.3.5 Miscellaneous

A. The copilot landing light switch and SET ALT HOLD switch should be relocated only after the recommendations of the preceding four paragraphs are incorporated (refer to paragraph 2.3.5).

3.3.4 Overhead Console

3.3.4.1 Fuel Control Selector Switches

A. The fuel control selector switches should be broken up into two sets of identical switches and be repositioned to both pilot and copilot collectives (refer to paragraph 2.4.1).

B. The toggle switches should be guarded with red covers in order to prevent accidental actuation (refer to paragraph 2.4.1).

3.3.4.2 Emergency Panel

A. The emergency panel should be moved to the center console (refer to paragraph 2.4.1).

3.3.4.3 Miscellaneous

C. The deficiencies found on the miscellaneous controls, heat and miscellaneous controls, and starting panels are numerous and appear too costly to correct on recently procured SH-2F aircraft (refer to paragraph 2.4.3).

3.3.5 Center Console

3.3.5.1 Engine Start System

A. The SH-2F engine start system should be eventually modified (refer to paragraph 2.5.1).

3.3.5.2 Pilot Communication Controls

A. The pilot communication control panels should be relocated to the overhead console (refer to paragraph 2.5.2).

3.3.5.3 Magnetic Anomaly Detector Control Panel

A. The MAD control panel should be relocated to the aircrew station (refer to paragraph 2.5.3).

3.3.5.4 Control Display Unit

A. The following systems and related panels should eventually be incorporated into a CDU: transponder, On Top Position Indicator (OTPI), TACAN, gyro compass and armament controls (refer to paragraph 2.5.4).

3.4 IMPLICATIONS

In an attempt to reduce government spending, with current military aircraft procurement costs in the millions of dollars, aircraft service lives are being extended to 30 and in some instances even 40 years. As does the SH-2F, most older generation cockpit designs suffer from a lack of expertise in ergonomics. Similar design principles used during the ergonomic engineering evaluation of the SH-2F cockpit could easily be applied to these older aircraft. Costs incurred in redesigning older aircraft cockpits are justifiable and are also necessary in that proper ergonomic placement of a poorly located switch may be all that is necessary to prevent an aircraft accident.

REFERENCES

REFERENCES

1. The Human Factors Crew Station Evaluation Guide. Unpublished: Naval Air Test Center, Patuxent River, Maryland, Undated

2. NAVAIR 01-260HCD-1, NATOPS Flight Manual for Navy Models SH-2F and HH-2D Aircraft, 15 December 1985, interim change 50 incorporated.

3. McFarland, Ross A. Ph.D. Human Factors in Air Transportation. New York: McGraw-Hill Book Co., 1953.

4. Alexander, David C. and Babur Mustafa Pulat. Industrial Ergonomics A Practitioner's Guide. Nocross, Georgia: Industrial Engineering and Management Press, 1985.

5. Reichardt, Harry L. NVG Compatible Filters For Various Light Sources. Unpublished: Presented at the Aerospace Lighting Institute Advanced School and Seminar in Los Angeles, 01 February 1989.

6. TM 11-5855-263-10, Army Operator's Manual for Aviator's Night Vision Imaging System AN/AVS-6(V)1 and (V)2, 05 July 1983.

7. Godfrey, George W. Crew Station Illumination. Unpublished: Presented for the Aerospace Lighting Institute, Undated.

8. Godfrey, George W. Principles of Display Illumination Techniques For Aerospace Vehicle Crew Stations. Tampa, Florida: Aerospace Lighting Institute, 1982.

9. Sells, S. B. Ph.D. and C. A. Berry Ph.D. Human Factors In Jet and Space Travel. New York: Ronald Press Co., 1961.

10. Federal Aviation Regulations Part 27, Airworthiness Standards: Normal Category Rotorcraft. Washington DC: U.S. Government Printing Office, 15 August 1985, changes 1-19 incorporated.

11. McCormick, Ernest J. Human Factors Engineering. Second Edition. New York: McGraw-Hill Book Co, 1964.

12. Interview with LCDR Peter LeVoci, SH-2F Model Manager, Naval Air Test Center, Patuxent River, Maryland, 21 November 1989.

13. NAVAIR 01-230HLH-1, NATOPS Flight Manual for Navy Model SH-3D/H Helicopters, 15 January 1983, interim change 36 incorporated.

14. NAVAIR A1-H60FB-NFM-000, Advance Copy NATOPS Flight Manual for Navy Model SH-60F Aircraft, 01 May 1989.

APPENDICES

APPENDIX A

FIGURES

Figure 1
SH-2F Port View

Figure 2
SH-2F Starboard View

Figure 3
SH-2F Port Quarter View

Figure 4
SH-2F Starboard Quarter View

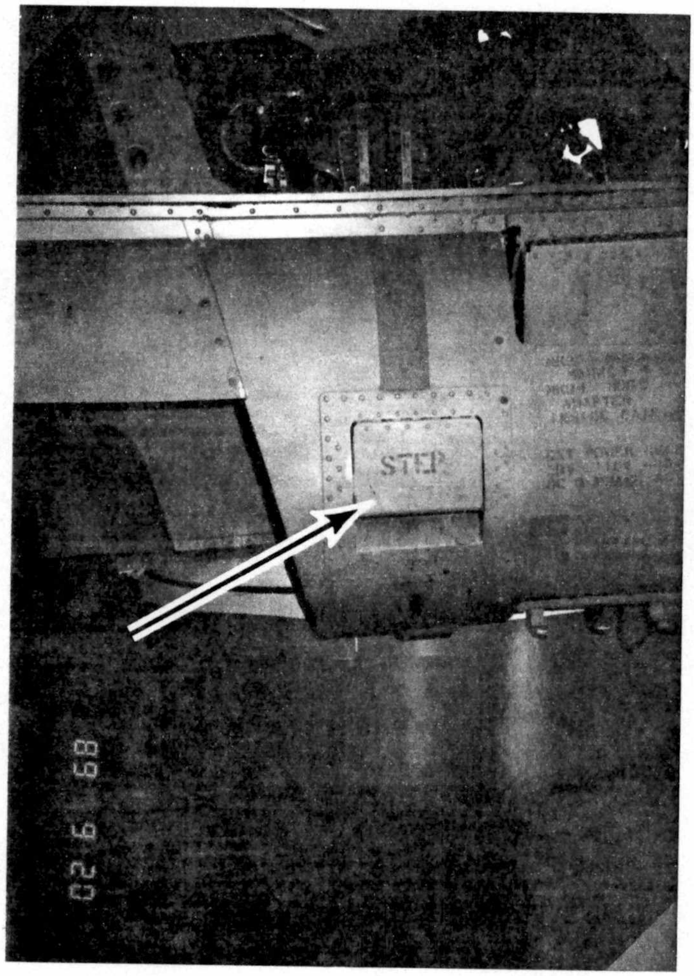

Figure 5
Kick-in Step

Figure 6
Boarding Ladder

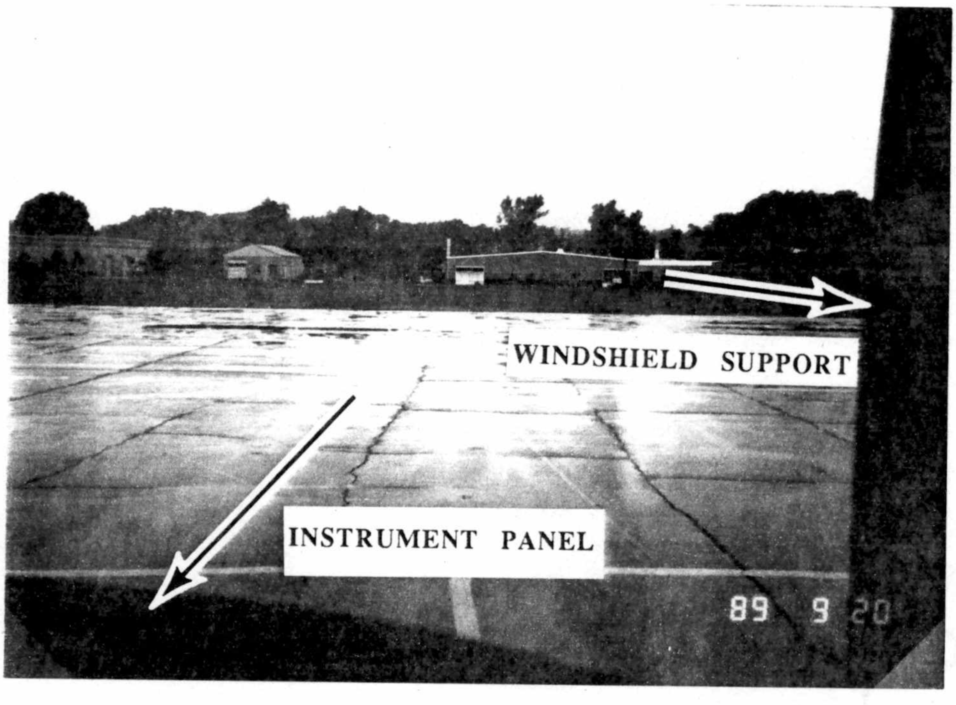

Figure 7
Pilot Field of View, Right Windshield

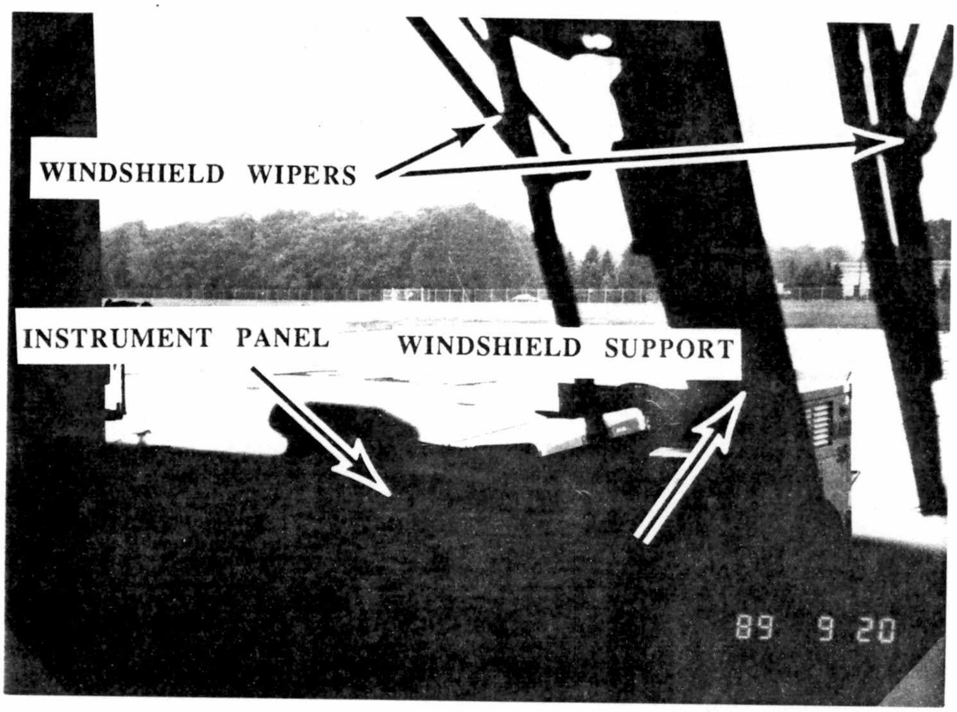

Figure 8
Pilot Field of View, Left Windshield

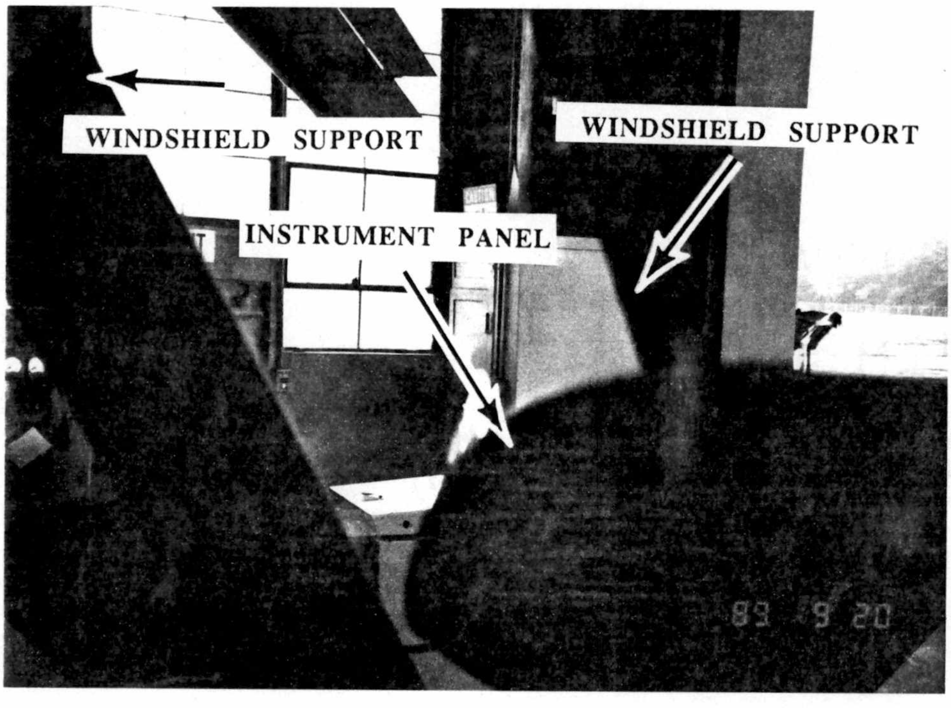

Figure 9
Pilot Field of View, Left Forward Quarter

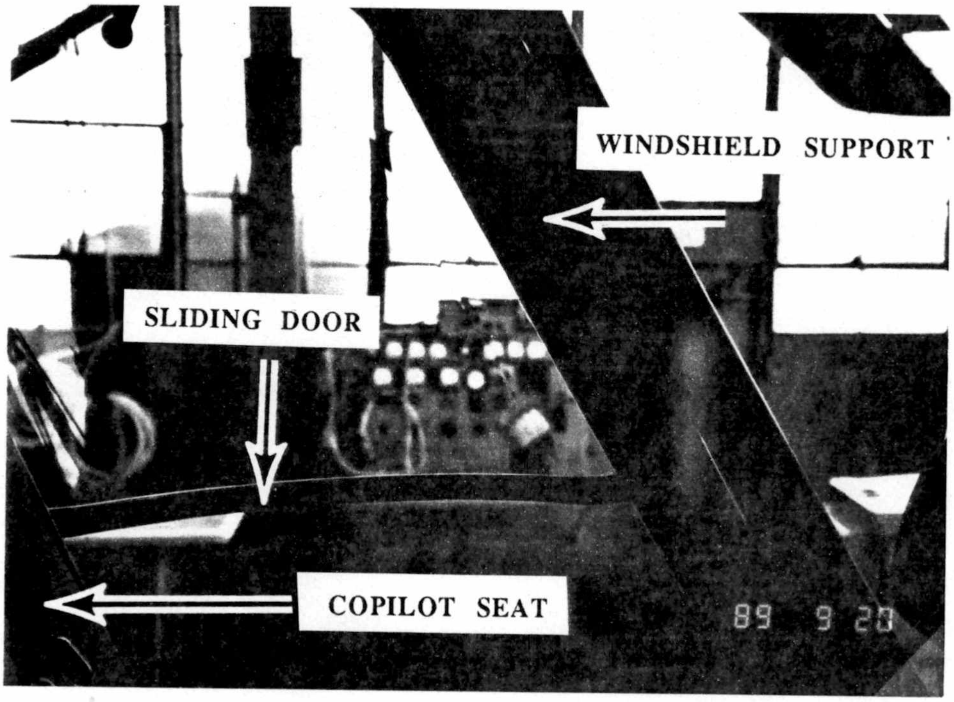

Figure 10
Pilot Field of View, 90 deg left

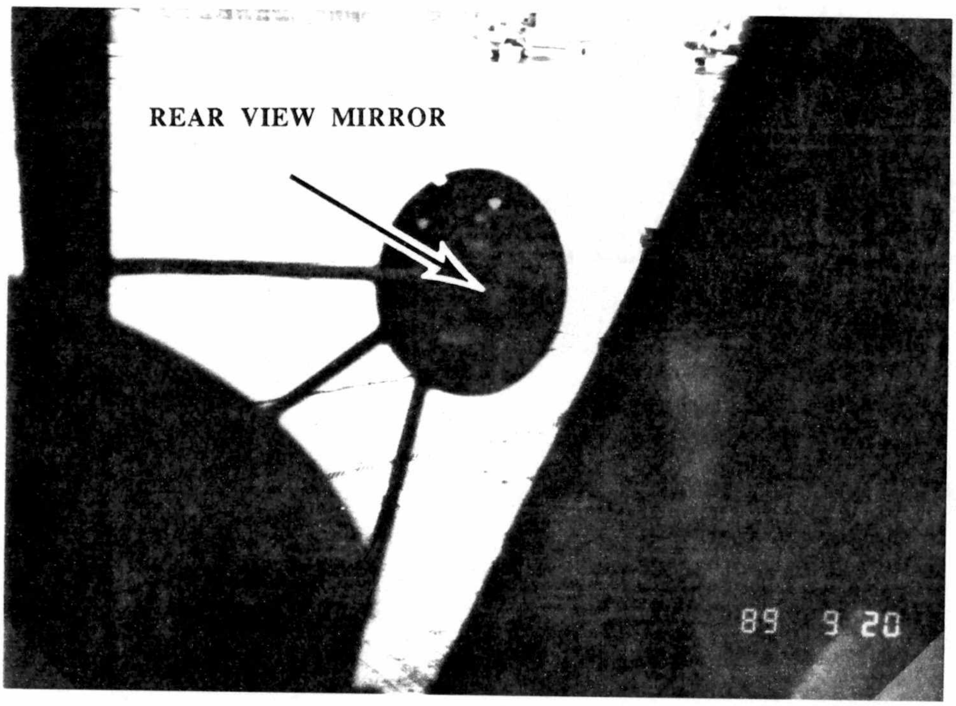

Figure 11
Pilot Field of View, Right Aft

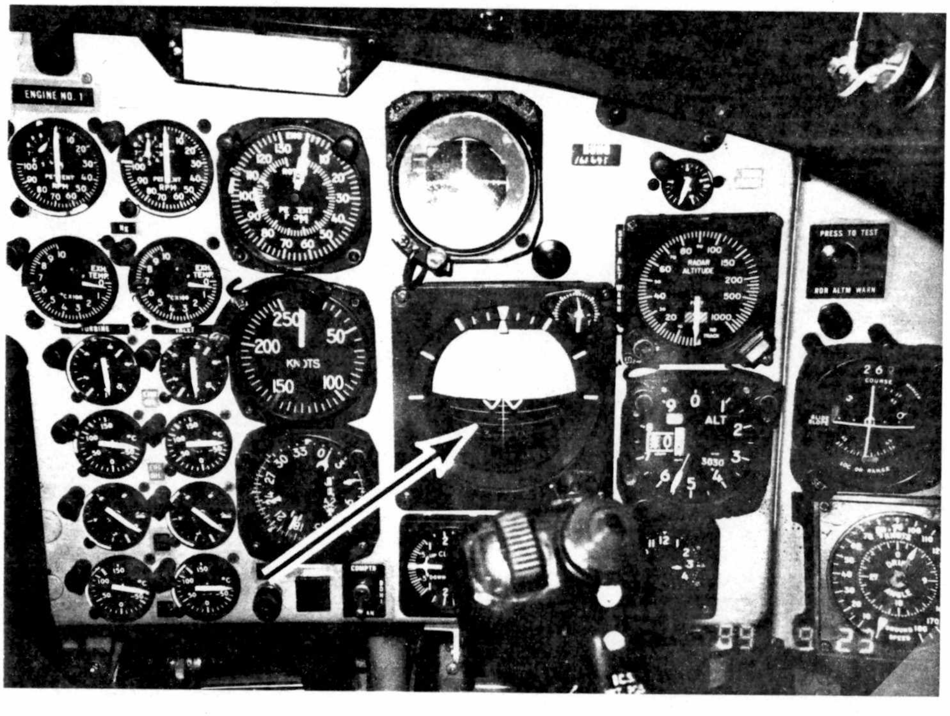

Figure 12
Attitude Indicator

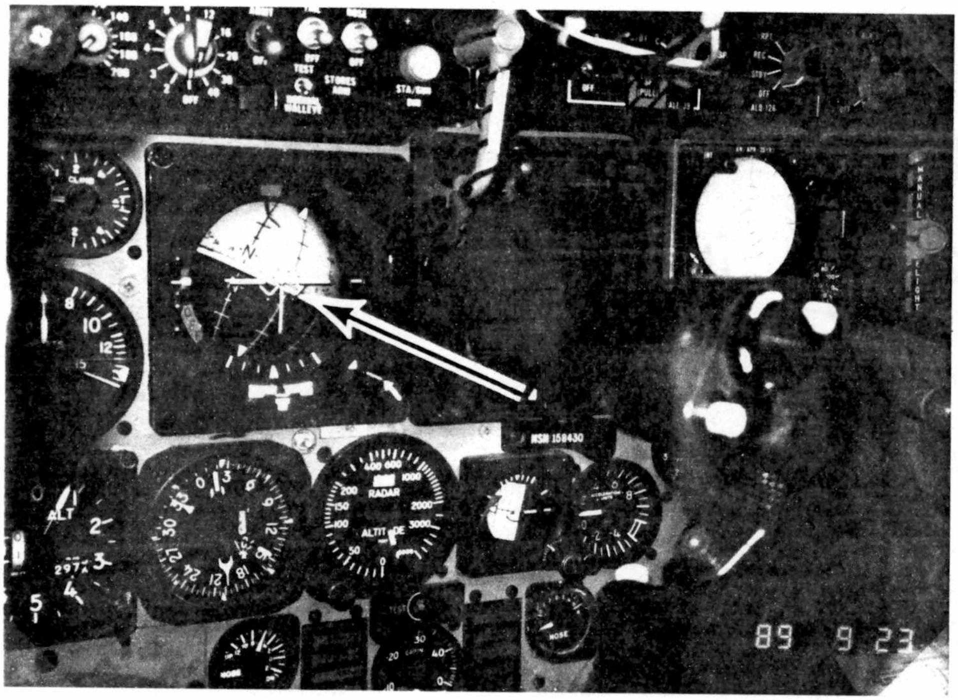

Figure 13
All-attitude Indicator

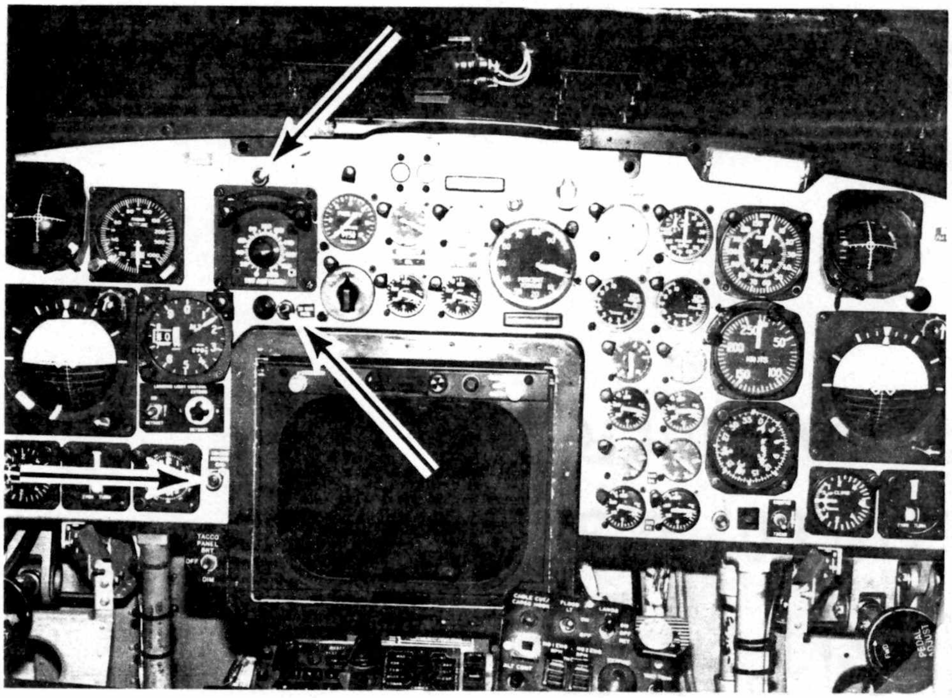

Figure 14
Warning and Advisory Lights, Left Side

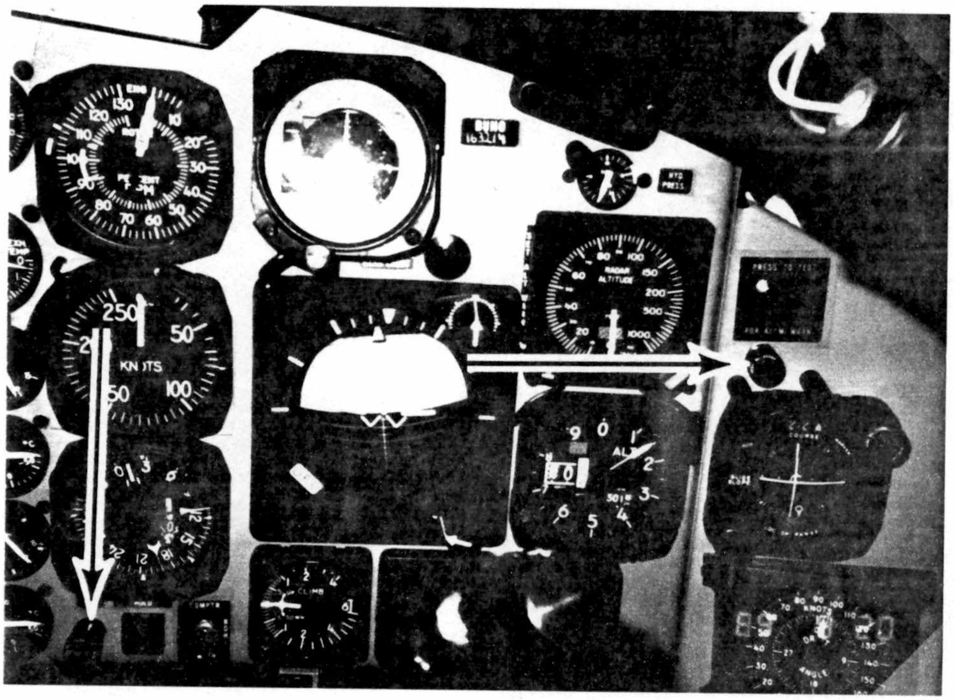

Figure 15
Warning and Advisory Lights, Right Side

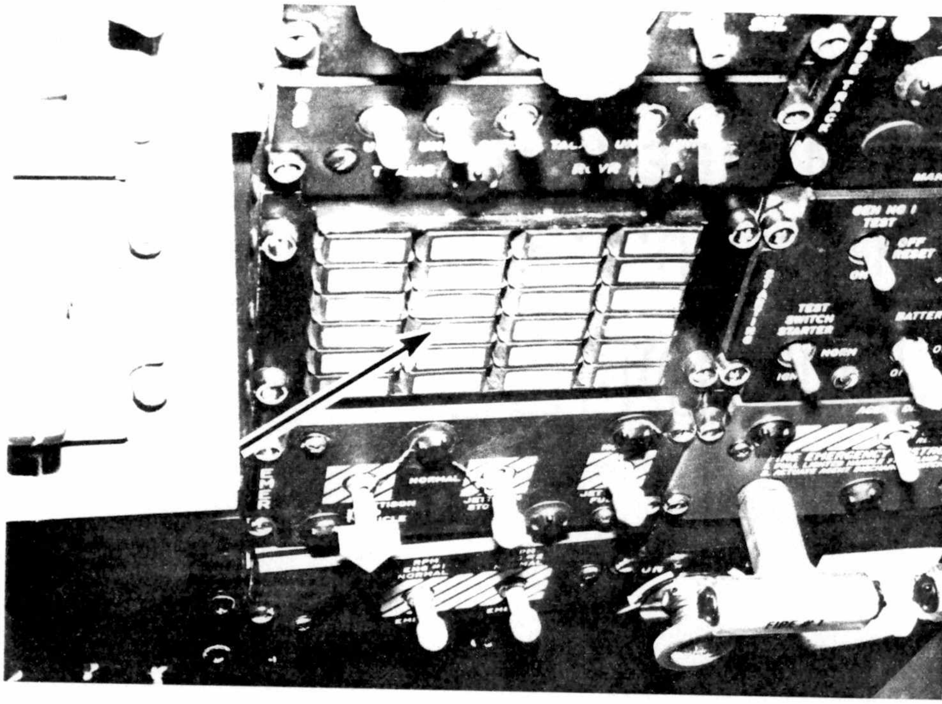

Figure 16
Caution Panel

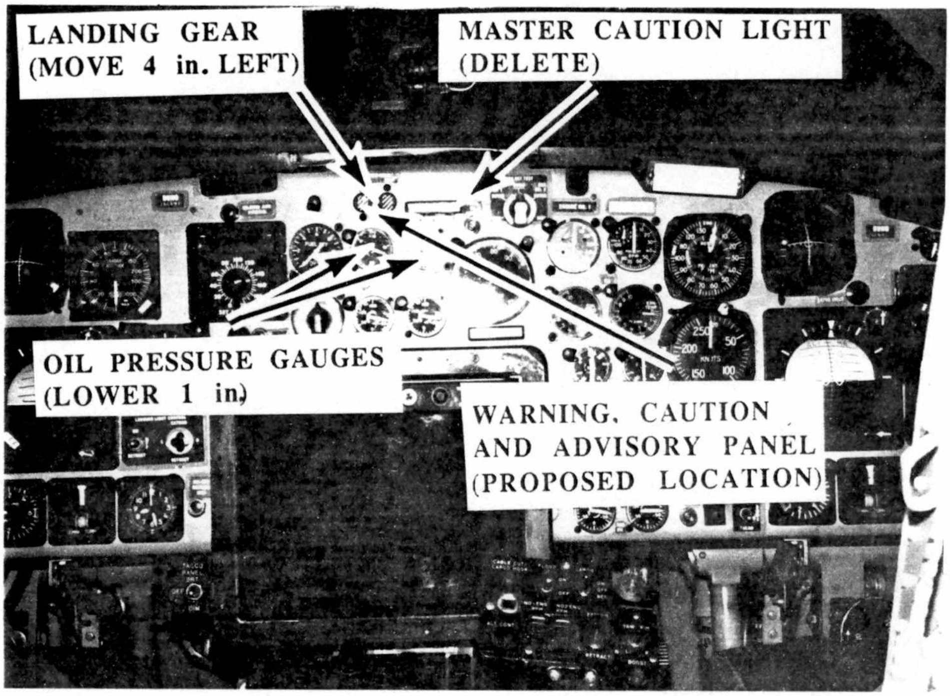

Figure 17
Proposed Warning, Caution and Advisory Panel Location

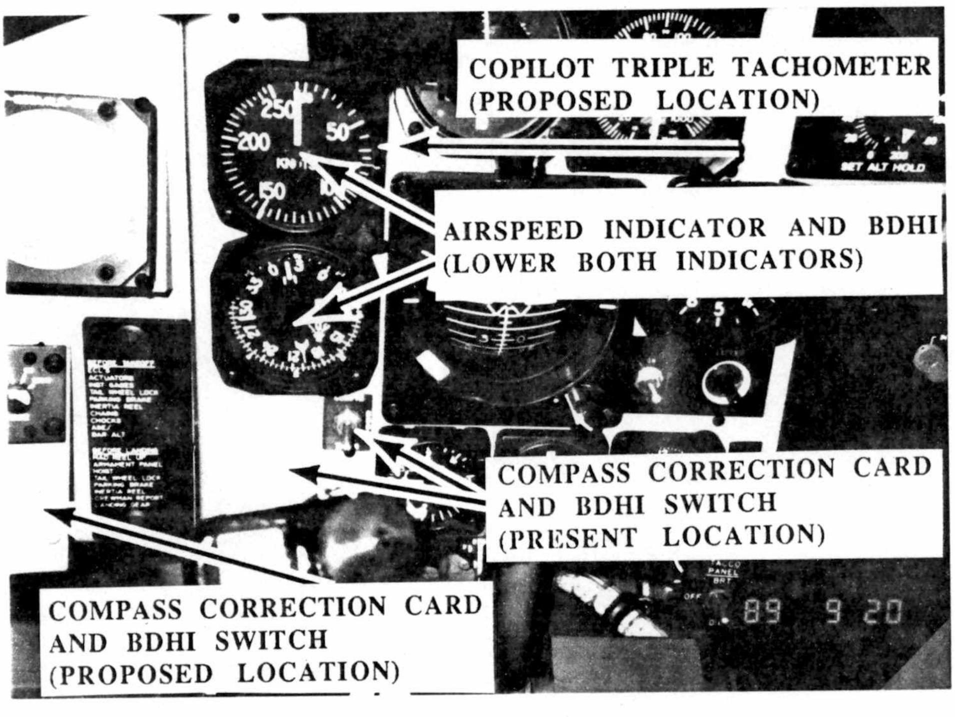

Figure 18
Proposed Copilot Triple Tachometer Location

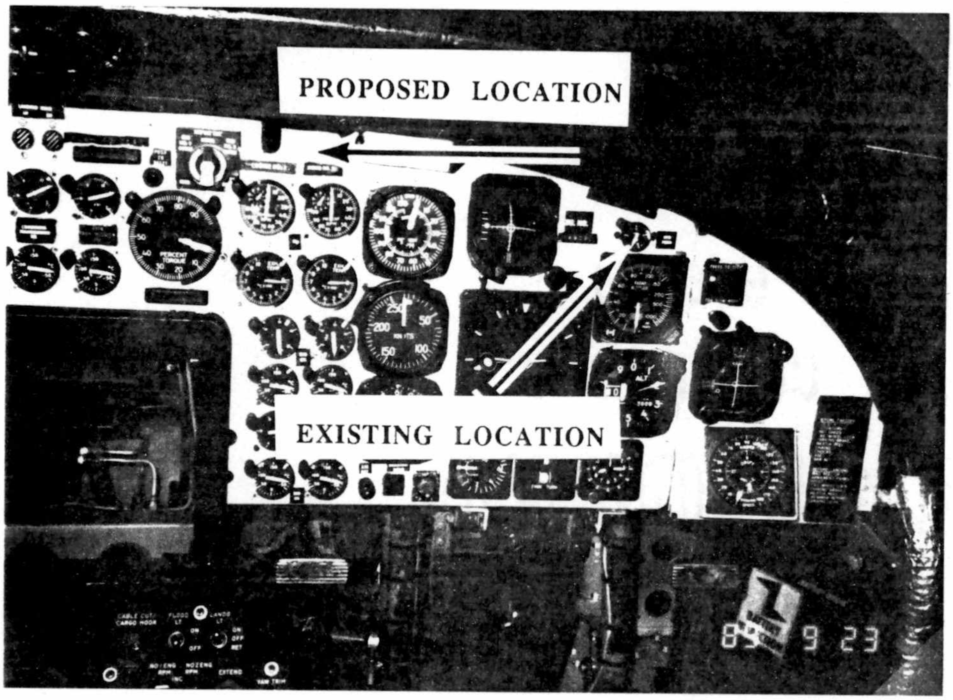

Figure 19
Utility Hydraulic Gauge

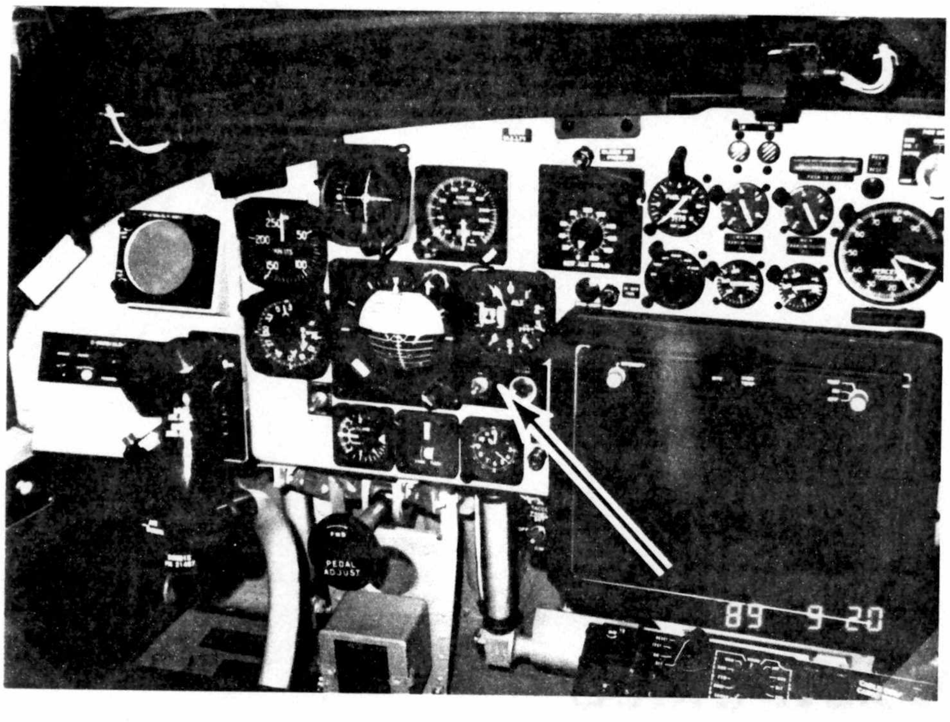

Figure 20
Copilot Landing Light Switches

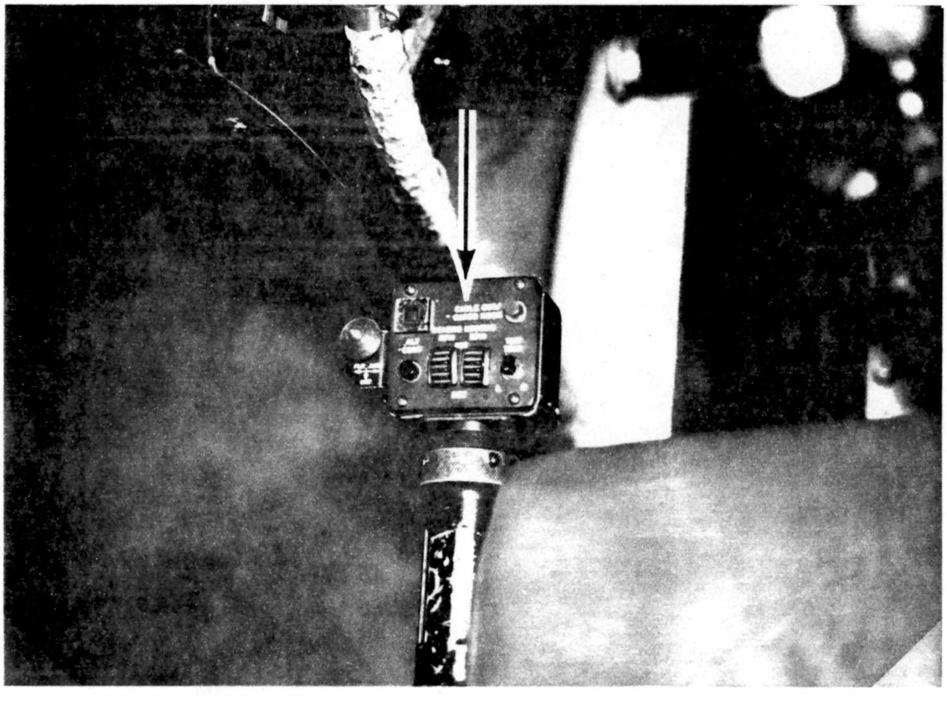

Figure 21
Proposed Copilot Landing Light Switches Location

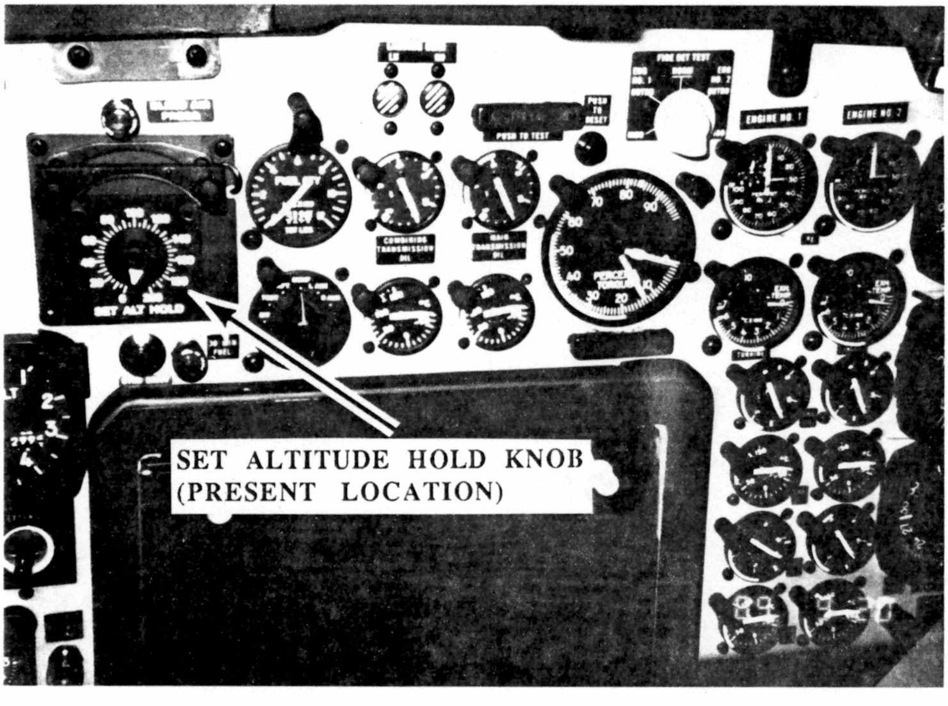

Figure 22
Set Altitude Hold Knob

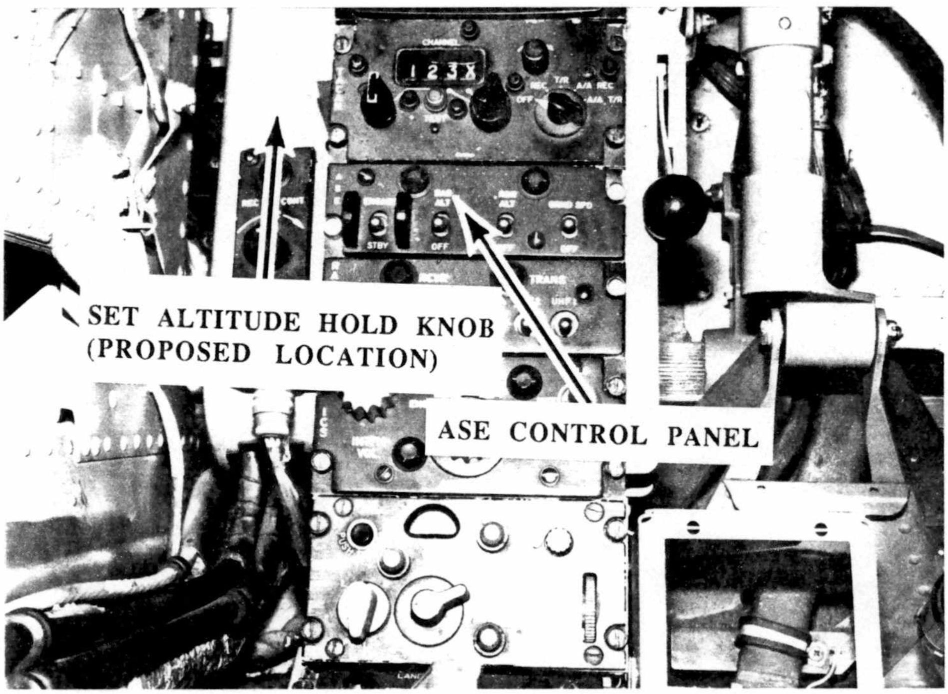

Figure 23
Proposed Set Altitude Hold Knob Location

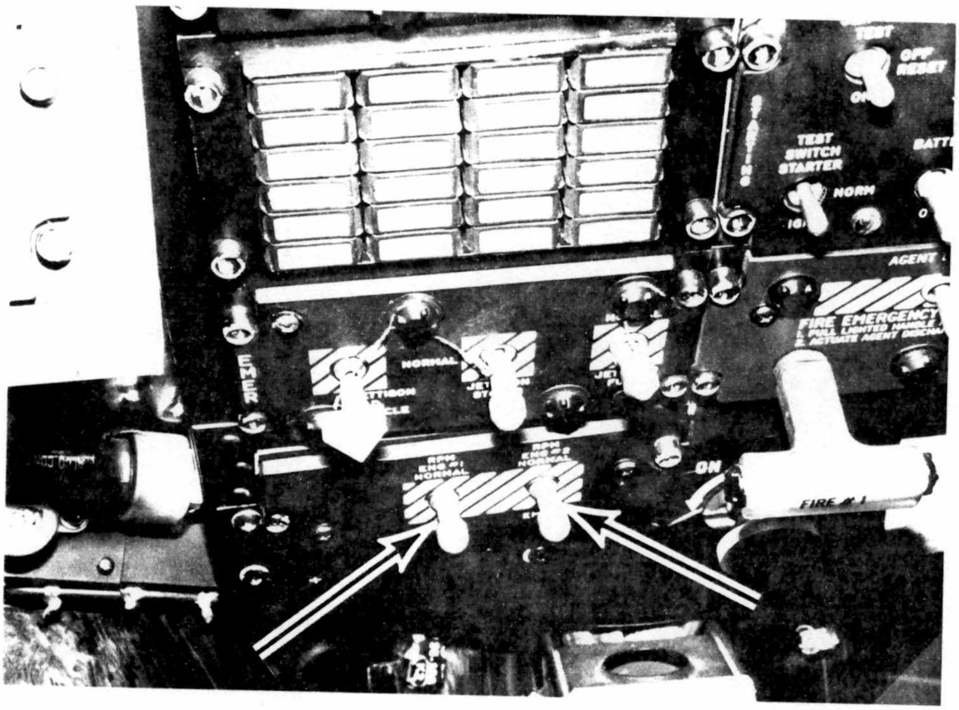

Figure 24
Fuel Control Selector Switches

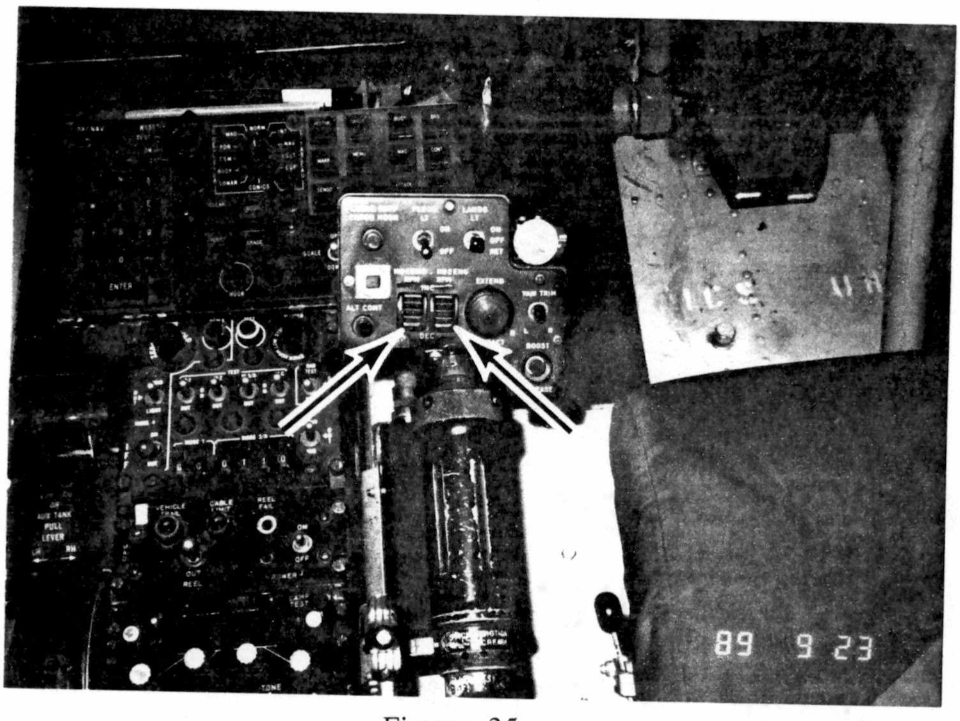

Figure 25
RPM Switches

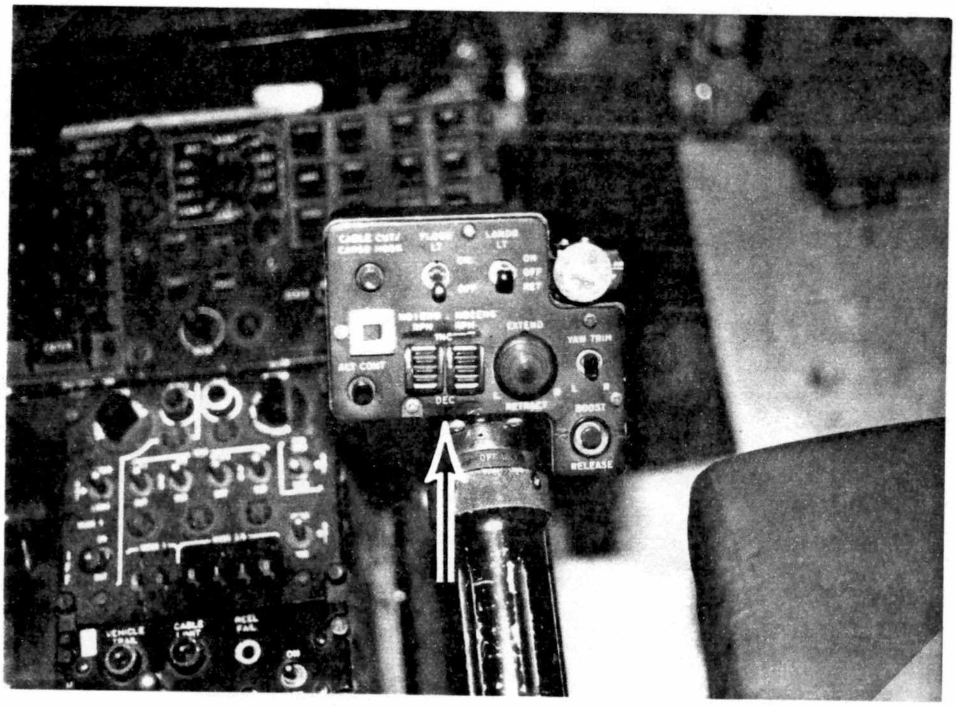

Figure 26
Proposed Location, Pilot Fuel Control Selector Switches

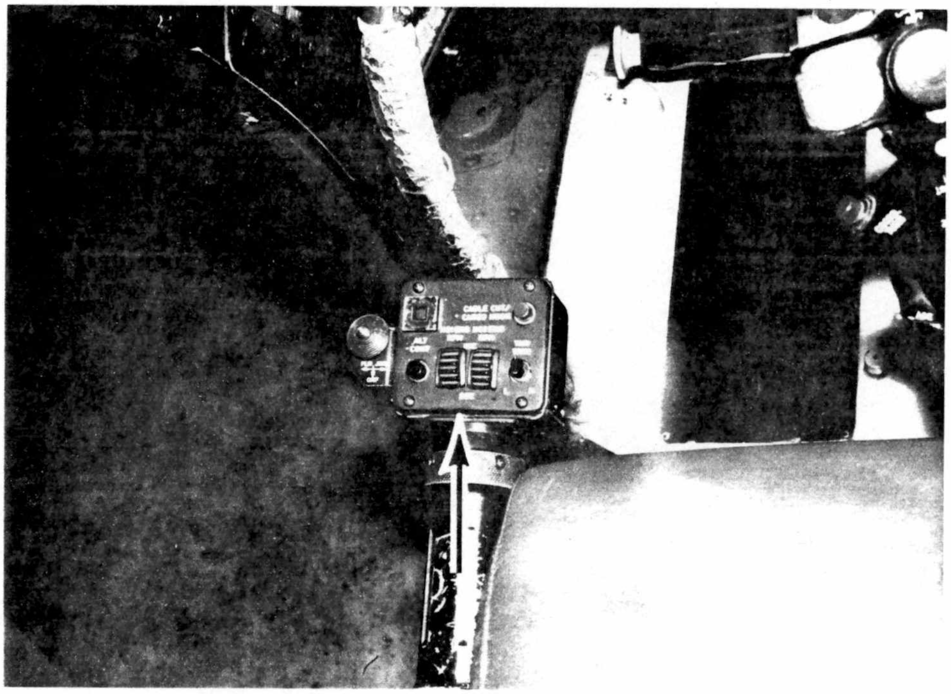

Figure 27
Proposed Location, Copilot Fuel Control Selector Switches

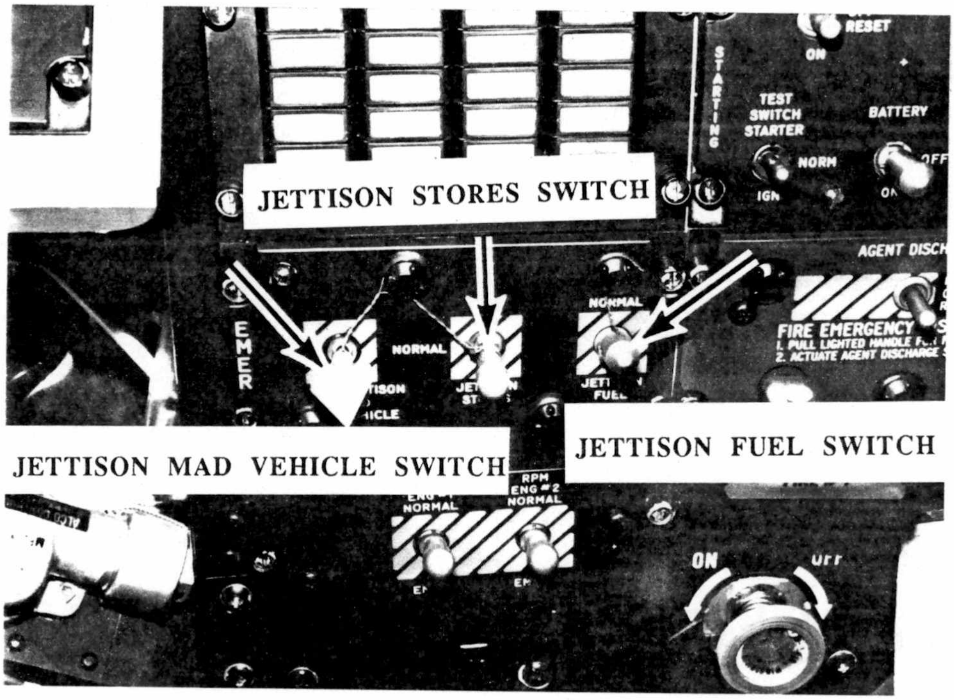

Figure 28
Emergency Panel

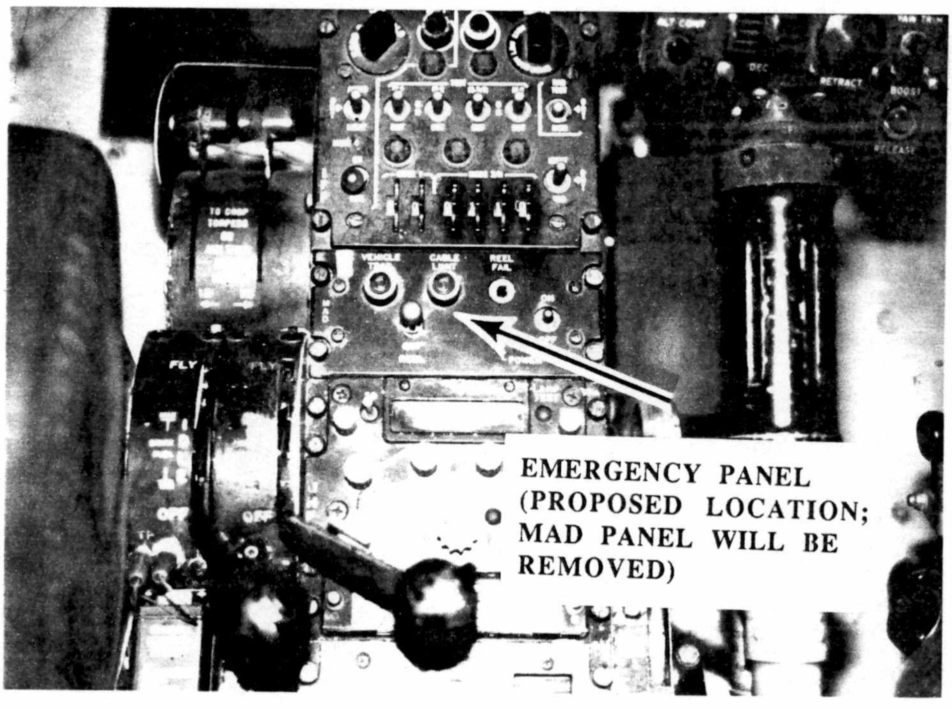

Figure 29
Proposed Emergency Panel Location

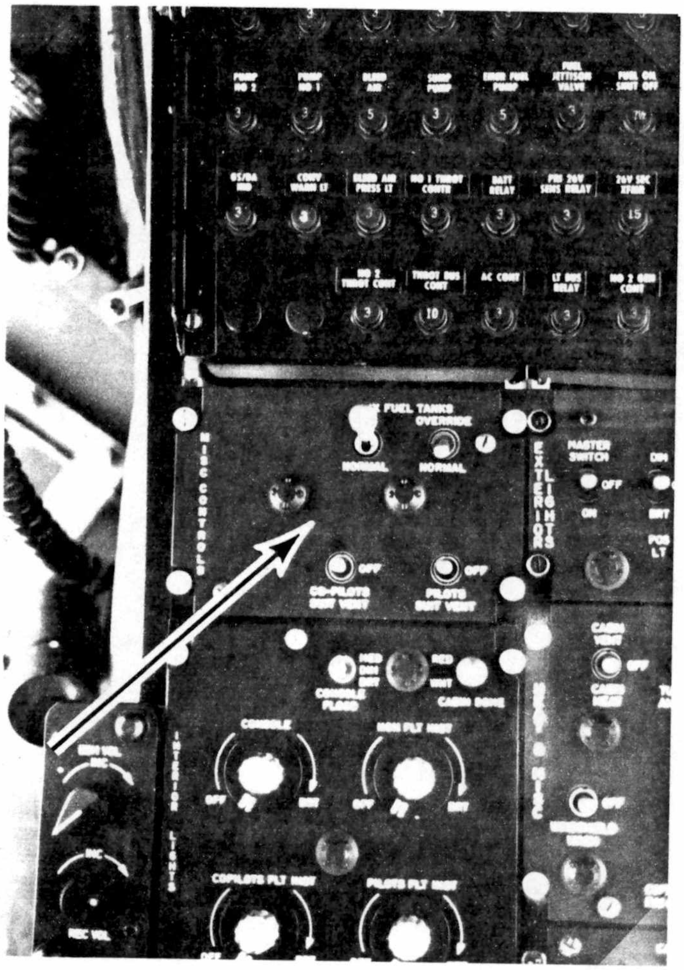

Figure 30
Miscellaneous Panel

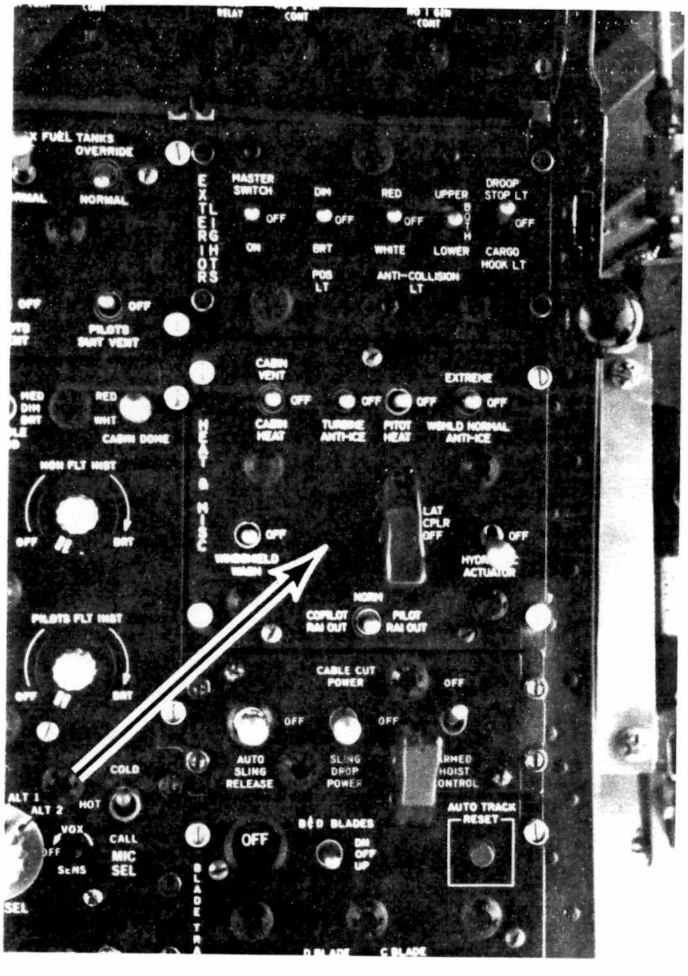

Figure 31
Heat and Miscellaneous Panel

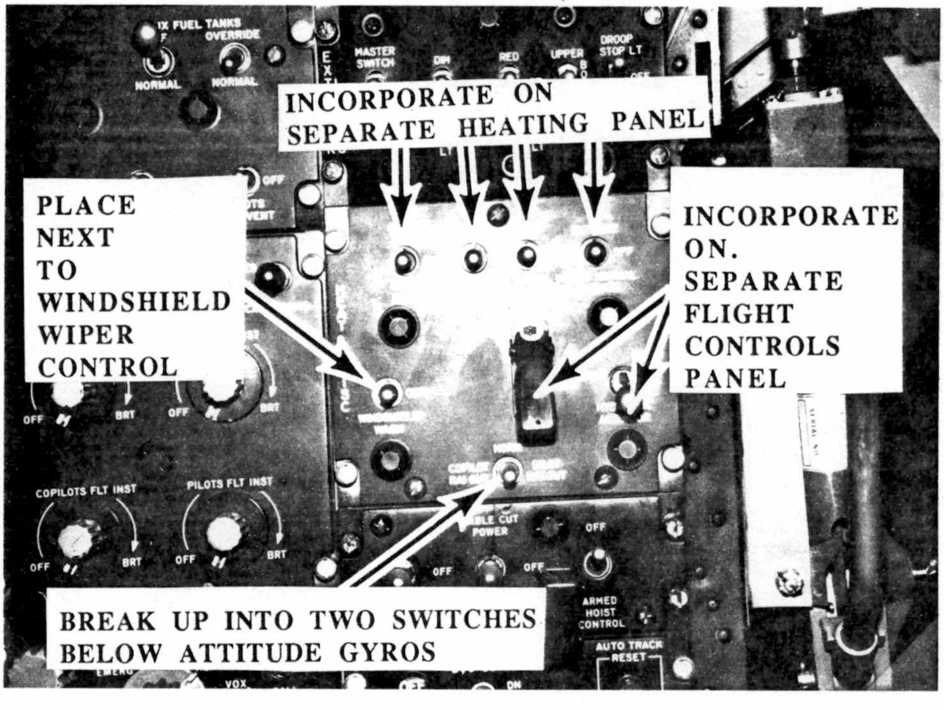

Figure 32
Proposed Miscellaneous Panel

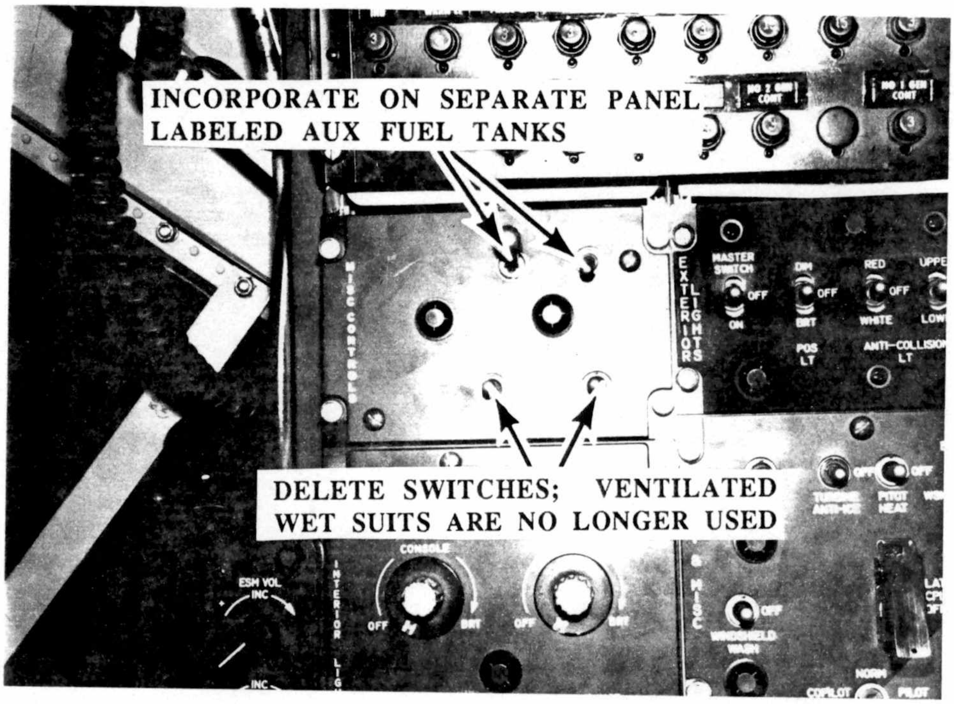

Figure 33
Proposed Heating Panel

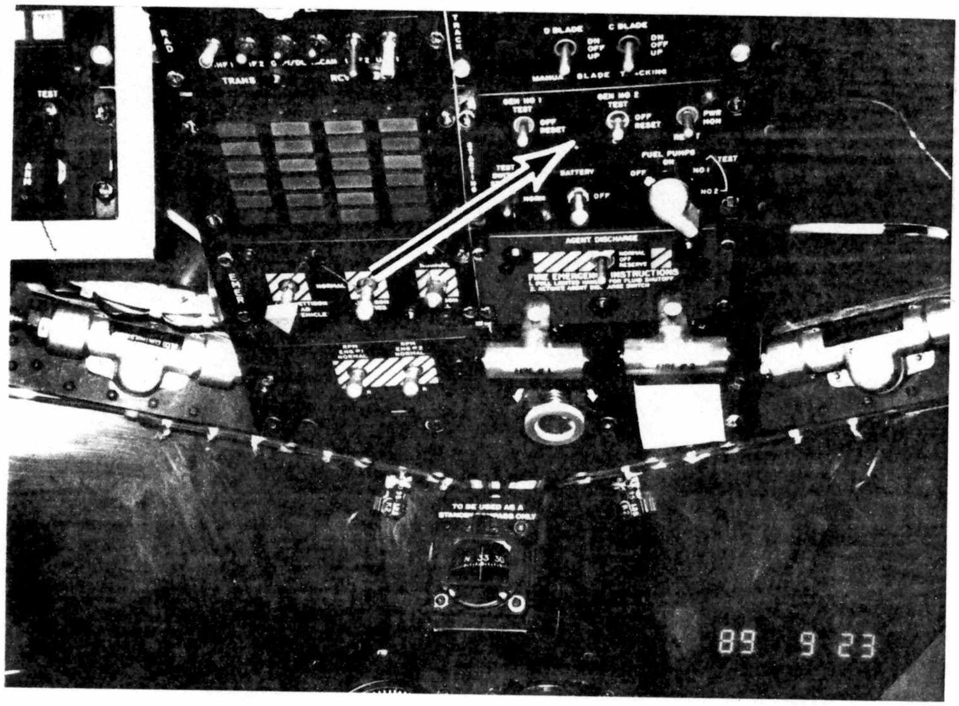

Figure 34
Starting Panel

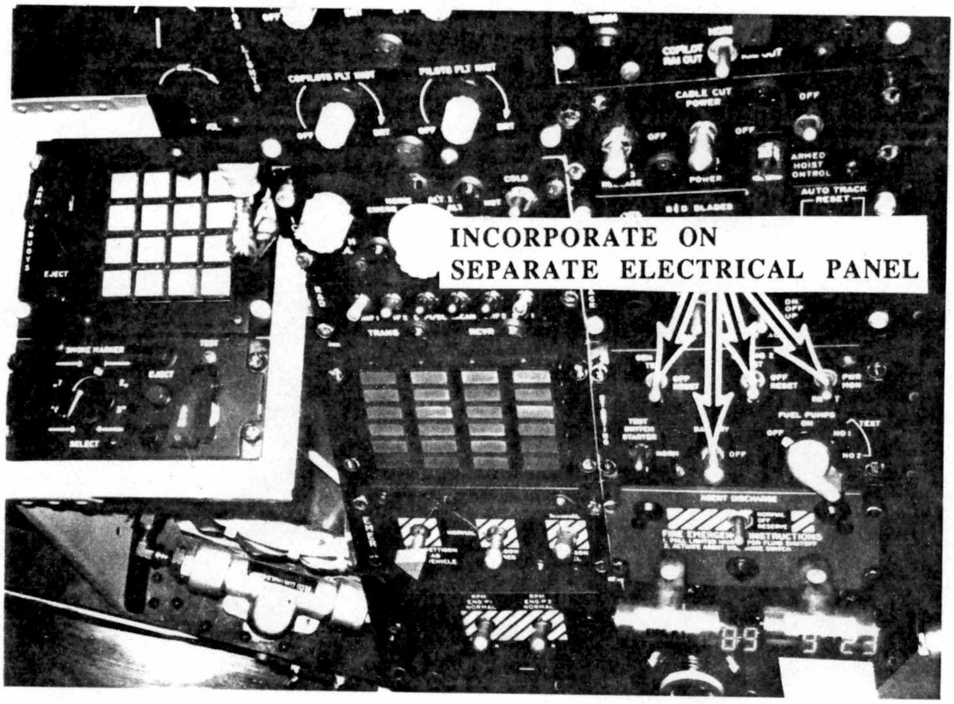

Figure 35
Proposed Starting Panel

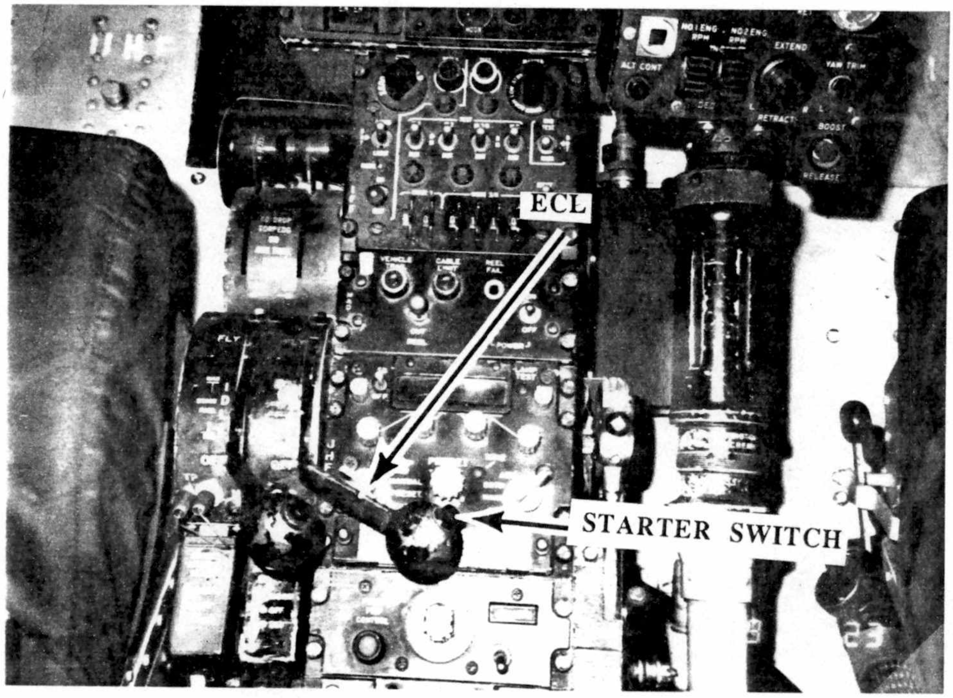

Figure 36
Starter Switches

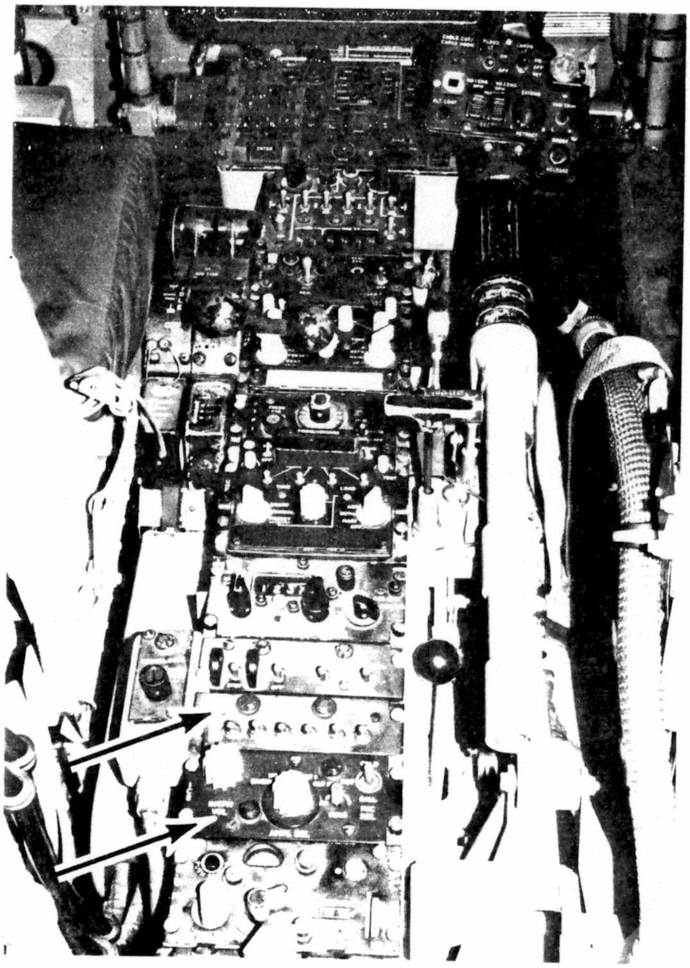

Figure 37
Pilot Communication Controls

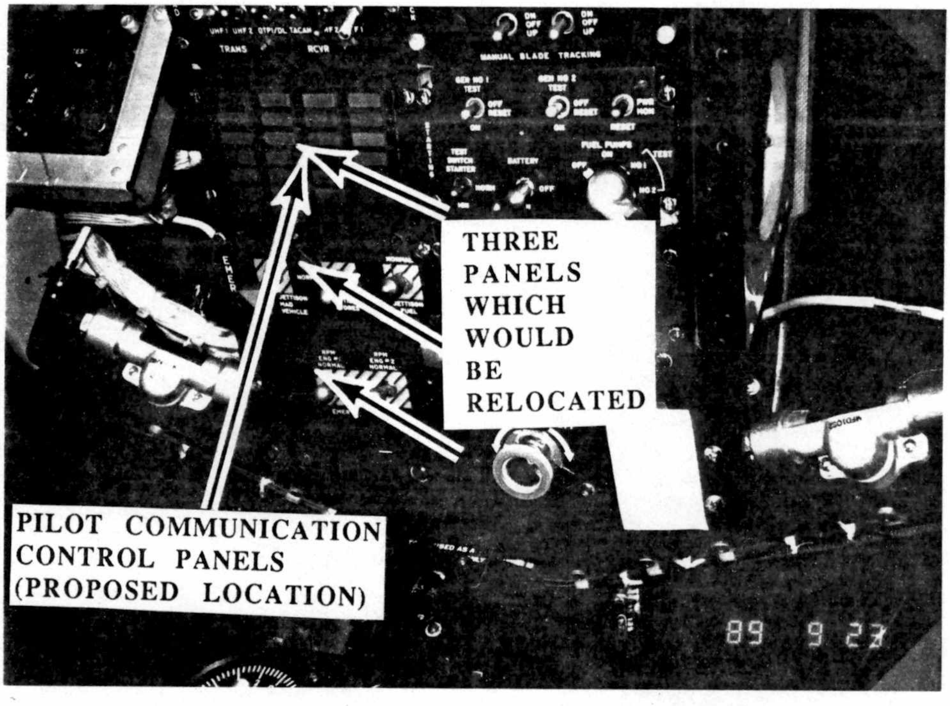

Figure 38
Proposed Pilot Communication Controls Location

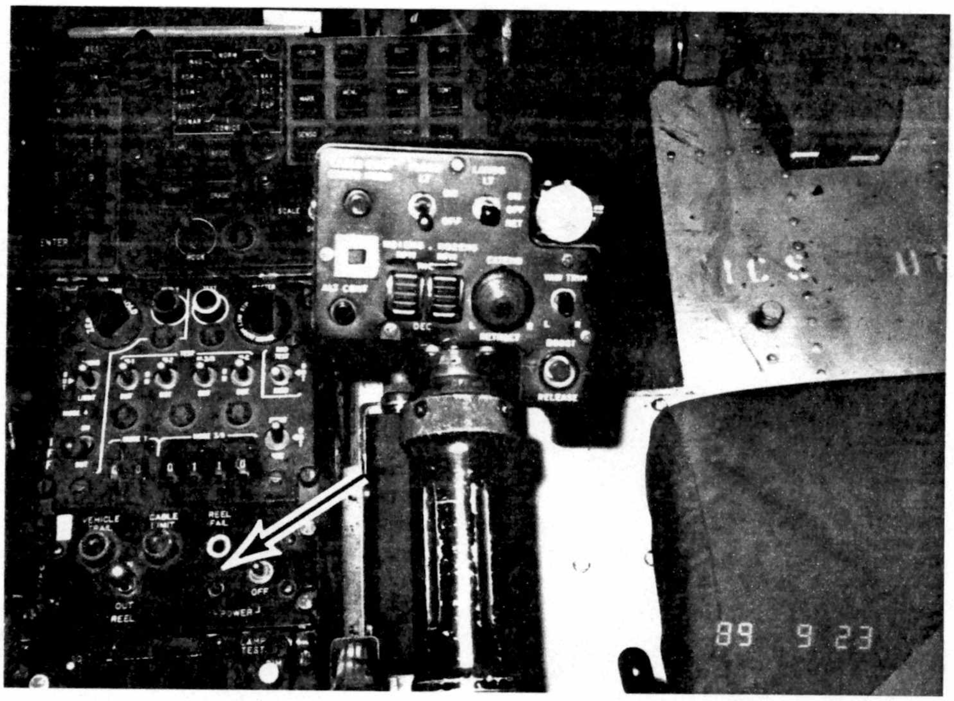

Figure 39
Magnetic Anomaly Detector Panel

Figure 40
Magnetic Anomaly Detector

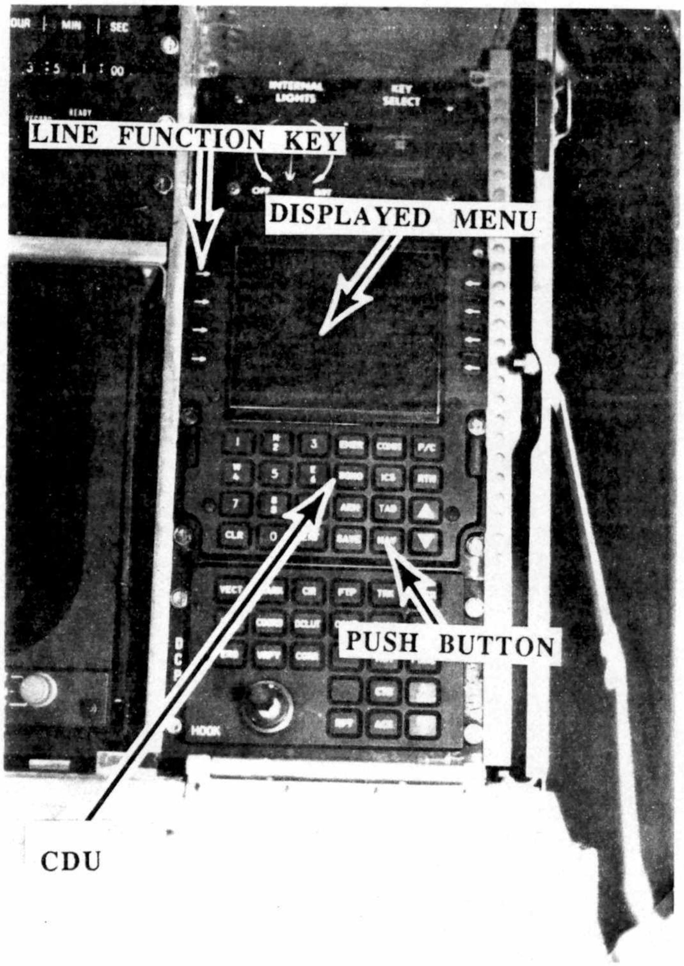

Figure 41
Control Display Unit

APPENDIX B

TABLES

Table I
AUTHOR ANTHROPOMETRIC DATA

Dimension		Percentile
Weight	180 lb	70%
Stature	70.0 in	55%
Sitting Height	38.5 in	95%
Trunk Height	25.5 in	95%
Shoulder Width	20.6 in	98%
Functional Reach	31.0 in	40%
Buttock-Knee Length	24.0 in	50%
Sitting Eye Height	33.0 in	90%

Note: Based on 1964 Navy and Marine Corps anthropometric data.

Table II
FLIGHT GEAR

Item	Weight
1. Flight Helmet	5 lb
2. Flight Gloves	<1 lb
3. Life Preserver and Vest	13 lb
4. Flight Suit	2 lb
5. Wet Suit	4 lb

Note: Items 1-4 are worn as summer flight gear. Items 1-5 are worn as winter flight gear.

Table III
APPLICABLE SPECIFICATION PARAGRAPHS

Specification Number and Title	Paragraph	Subject
MIL-STD-250D: Aircrew Station Controls and Displays for Rotary Wing Aircraft	4.1	Selection of Controls and Displays
	4.2	Location of Controls and Displays
	4.3	Assignment of Controls to Crew
	4.4	Actuation of Controls
	4.5	Displayed Information
	4.6	Control Knobs, Handles and Switches
	4.7	Cockpit Dimensions
	4.8	Ground Maintenance Controls and Displays
	4.9	Cockpit Equipment Arrangement
	5.1.1	Checkoff Lists
	5.1.2	Anti-Torque Pedals
	5.1.3	Anti-Torque Pedal Adjustment
	5.1.4	Cyclic Pitch Control
	5.1.5	Collective Pitch Control
	5.1.6	Control System Power Boost Control
	5.1.7	Automatic Flight Control System
	5.1.8	Flight Trim Controls
	5.1.9	Force Trim
	5.1.10	Landing Gear Control
	5.1.11	Alternate Landing Gear Control
	5.1.12	Landing Gear Position Indicators
	5.1.13	Wheel Brake Controls
	5.1.14	Parking Brake Control
	5.1.15	Wheel Centering Lock
	5.1.16	Rotor Brake Control
	5.2.2.1	Engine Conditioner Control
	5.2.2.2	Engine Speed Trim Control
	5.2.6	Fuel System Selector Controls
	5.2.7.2	Gas Turbine Engine Ignition Control Switches
	5.2.8	Ground Start Switch
	5.2.9	Stop Switch
	5.3	Fire Fighting System Controls
	5.4.1	Master Electrical Control Switches Including Battery, Generator and Inverter
	5.4.2	Lighting and Miscellaneous Switches
	5.4.3	Landing Light and Search Light Switches
	5.4.4	Circuit Protective Device

Table III
(Continued)

Specification Number and Title	Paragraph	Subject
	5.4.5	Radio, Radar and Navigation Controls
	5.5.1	Instrument Panel General Design
	5.5.2	Basic Flight Instrument Group
	5.5.3	Engine Instruments
	5.5.4	Standby Compass
	5.6.1	Armament Controls General Requirements
	5.6.3	External Stores Controls
	5.7.6	Defrosting, Deicing, Pitot Heat, Cockpit Air Conditioner and Windshield Controls
	5.7.9	Safety Shoulder Harness Locking Control
	5.7.12	Map Stowage
MIL-STD-850: Aircrew Station Vision Requirements for Military Aircraft	4.1.1	Extent of External Vision
	4.1.3	Quality of External Vision
	8.1	Helicopters; Side by Side
MIL-STD-1472C: Human Engineering Design Criteria For Military Systems, Equipment and Facilities	Visual Displays	
	5.2.1.1	Display Illumination
	5.2.1.2	Light Distribution
	5.2.1.3	Information
	5.2.1.4	Location and Arrangement
	5.2.1.5	Coding
	Controls	
	5.4.1.1	Selection
	5.4.1.2	Direction of Movement
	5.4.1.3	Arrangement and Grouping
	5.4.1.4	Coding
	5.4.1.5	Labeling of Controls
	5.4.1.6	Compatibility with Hardware
	5.4.1.8	Prevention of Accidental Activation
	5.4.2.1	Discrete Rotary Controls
	5.4.3.1	Discrete Linear Controls
	5.4.3.2	Continuous Adjustment Linear Controls
		Labeling
	5.5.1.1	General Requirements
	5.5.1.2	Label Characteristics

Table III
(Continued)

Specification Number and Title	Paragraph	Subject
	5.5.2.1	Orientation
	5.5.2.2	Location
	5.5.2.3	Standardization
	5.5.3.1	Equipment Functions
	5.5.3.2	Abbreviations
	5.5.4.1	Brevity
	5.5.4.2	Familiarity
	5.5.4.3	Visibility and Legibility
	5.5.5	Design
		Anthropometry
	5.6.1	General
	5.6.2	Anthropometric Data
	5.6.3	Use of Data
		Safety
	5.13.1	General
	5.13.2	Safety Labels and Placards
		Aerospace Vehicle Compartment Design Requirements
	5.14.1	Windows, Canopies and Windshields
	5.14.2	Crew Stations and Passenger ompartments
	5.14.3	Personnel Ingress and Egress
	5.14.4	Emergency Evacuation

Table IV
SUMMARY DATA: 1964 U.S. NAVY AND MARINE CORPS ANTHROPOMETRIC SURVEY

Measurement (in)	Percentile (%)
Sitting Eye Height	
28.81	1
29.19	2
29.41	3
29.70	5
30.11	10
30.38	15
30.59	20
30.77	25
30.94	30
31.09	35
31.23	40
31.38	45
31.52	50
31.67	55
31.82	60
31.98	65
32.15	70
32.33	75
32.55	80
32.80	85
33.12	90
33.61	95
33.93	97
34.16	98
34.52	99
Functional Reach	
28.56	1
28.87	2
29.07	3
29.33	5
29.75	10
30.03	15
30.27	20
30.48	25
30.68	30
30.86	35
31.04	40
31.22	45
31.40	50
31.59	55

Table IV
(Continued)

Measurement (in)	Percentile (%)
31.78	60
31.98	65
32.20	70
32.44	75
32.71	80
33.03	85
33.44	90
34.04	95
34.42	97
34.70	98
35.11	99

Table V
COCKPIT TEMPERATURE LEVEL DATA

Flight Condition	Airspeed (knots)	Altitude (ft)	Temperature (deg F) Pilot Head	Pilot Foot	Copilot Head	Copilot Foot
Hover	0	10	80	82	80	82
Hover	0	10	81	79	81	79
Cruise	70	300	80	82	80	82
Cruise	100	300	87	82	87	82
Maximum Continuous Power	140	300	88	84	88	84

Table VI
COCKPIT NOISE LEVEL DATA

Flight Condition	Airspeed (knots)	Altitude (ft)	Noise Level (db)
Ground Idle	0	0	78.7
Hover	0	10	79.7
Cruise	70	300	76.8
Cruise	100	300	78.4
Maximum Continuous Power	130	300	83.4

Note: Computer generated predictions for noise levels pilots will encounter while wearing the current SPH-3C sound attenuation helmet.

APPENDIX C

DESIGN EYE POSITION CALCULATIONS

DESIGN EYE POSITION CALCULATIONS

The design eye position (DEP) is defined as the point in space located at the sitting eye height of the fiftieth percentile aviator as measured vertically above the neutral seat reference point (NSRP) and 13 in measured horizontally forward of the seat back tangent line. The NSRP is that point in space located at the seat's mid-point of vertical adjustment.

In order for the author to situate himself at the DEP, the following calculations as referenced to the cockpit deck were performed:

Distance from cockpit deck with seat full up	(a)	11 1/4 in
Distance from cockpit deck with seat full down	(b)	4 3/4 in
Seat vertical range of travel	(a-b)	6 1/2 in
NSRP	c = (b) + 1/2(a-b)	8 in
Sitting eye height of author - 90% aviator	(d)	33 in
Sitting eye height of 50% aviator	(e)	31 1/2 in
Difference	f = (d-e)	1 1/2 in
Seat height for author to be situated at DEP	(c-f)	6 1/2 in

APPENDIX D

GLOSSARY OF TERMS

GLOSSARY OF TERMS

AUTOMATIC STABILIZATION EQUIPMENT: A type of automatic flight control system designed to provide airspeed hold, roll attitude hold and heading hold through continuous flight control system inputs via hydraulic actuators.

BEARING DISTANCE HEADING INDICATOR: An analog gauge which displays aircraft heading as well as TACAN station bearing and distance.

COLLECTIVE: A control stick which allows pilots to command desired aircraft power setting by changing pitch on all main rotor blades equally .

CYCLIC: A control stick which allows pilots to command desired aircraft pitch and roll attitude by varying main rotor blade pitch.

DESIGN EYE POSITION: The point in space located at the sitting eye height of the fiftieth percentile aviator as measured vertically above the NSRP and 13 in measured horizontally forward of the seat back tangent line.

FULLY-ARTICULATED: A type of rotor system designed to permit blades to both lead and lag as well as flap in order to lessen inherent main rotor vibration.

FIELD-OF-VIEW: The extent of the pilot's external view from the cockpit.

GEARBOX: An aircraft transmission.

KICK-IN-STEP: An entry and egress step which incorporates a hinged face plate. Pilots must kick-in the hinged face plate in order to gain access to the step.

LINE-UP LINES: White lines in order to aid the pilot in maintaining proper aircraft orientation for landing.

MAIN ROTOR: The rotor system which provides primary lift for the helicopter.

NIGHT VISION GOGGLES: A device which allows pilots to see out of the cockpit in near total darkness by amplifying ambient light in the red and near infrared wavelengths.

NEUTRAL SEAT REFERENCE POINT: That point in space located at the seat's mid-point of vertical adjustment.

ON TOP POSITION INDICATOR: A device which provides pilots azimuth information to a selected radio frequency in order to allow the aircraft to be flown to the source of the frequency.

TACTICAL AIR NAVIGATION: A navigation device which provides pilots aircraft azimuth and slant range information to a selected ground station.

TAIL ROTOR: The rotor system which provides pilots aircraft directional control.

TURBOSHAFT ENGINE: A gas turbine design used by helicopters in which engine thrust is used to drive a free turbine wheel which in turn ultimately provides power to the rotor systems via the transmission systems.

VERTIGO: A sensation of dizziness and a feeling of whirling about.

APPENDIX E

LIST OF ABBREVIATIONS

LIST OF ABBREVIATIONS

ASE	Automatic Stabilization Equipment
ASW	Antisubmarine Warfare
BDHI	Bearing Distance Heading Indicator
dbA	decibel
CDU	Control Display Unit
DEP	Design Eye Position
deg	degrees
ECL	Engine Condition Lever
FOV	Field of View
ft	feet
IMC	Instrument Meteorological Conditions
ICS	Intercommunication System
in	inches
LAMPS	Light Airborne Multi Purpose System
lb	pounds
NAV	Navigation
NVG	Night Vision Goggles
NG	Gas Generator Speed
NR	Main Rotor Speed
NSRP	Neutral Seat Reference Point
OTPI	On Top Position Indicator
psi	pounds per square inch
RAI	Remote Attitude Indicator
TACAN	Tactical Air Navigation

VITA

Anthony Vanaria IV was born in Waltham, Massachusetts on 11 November 1957. He attended Waltham High School and graduated in 1975. Following High School, he attended the U.S. Naval Academy Preparatory School and, in July 1976, entered the U.S. Naval Academy, graduating in May 1980 with a Bachelor of Science Degree in Ocean Engineering. Following graduation, he attended and completed pilot flight training and was designated a Naval Aviator in September 1981. Following designation, he completed tours at the Naval Air Station, Key West Florida and in Helicopter Antisubmarine Squadron Seventeen (HS-17). While in HS-17, he deployed to the Mediterranean aboard the aircraft carrier U.S.S. Coral Sea (CV-43). In 1986, he applied and was accepted for test pilot training at the U.S. Naval Test Pilot School, Patuxent River, Maryland and graduated with Class 92 in December 1987. He is currently assigned as a test pilot at the Rotary Wing Aircraft Test Directorate, Naval Air Test Center, Patuxent River Maryland and is involved with H-3 and H-60 flight tests. He enrolled in the Graduate School of the University of Tennessee, Knoxville, in May 1987. He will continue as a test pilot after graduation.