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INTEGRATED INFORMATION PRESENTATION AND CONTROL SYSTEM STUDY

Volume III - Degraded Mode Analysis

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FOREWORD

This volume documents the results of work conducted under USAF Contract F33615-70-C-1832 by Advanced Crewstation Technology Laboratory personnel, Military Airplane Systems Division, The Boeing Company, Seattle, Washington. The objective of this work was to refine the basic control and display concepts developed under Contract F33615-69-C-1544 by considering contingency operations in the mission.

The contract was initiated jointly under Project No. 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles," which is managed by Mr. John H. Kearns, III, as Project Engineer and Principal Scientist for the Flight Deck Development Branch (FGR), Flight Control Division, Air Force Flight Dynamics Laboratory, and under Project 4167, "Integrated Avionics," which is managed by Mr. Richard D. Alberts, as Project Engineer for the Plans Office (XP), Air Force Avionics Laboratory. The work was performed as a part of Task 6190 21, "Advanced Integrated Fighter Cockpit Development Program," under the guidance of Mr. Robert R. Davis, Group Leader, and Capt. N. A. Kopchick (FGR) as Task Engineer.

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The work effort covered the period from June 1970 through March 1971. This volume was submitted by the authors in April 1971 for publication as an AFFDL Technical Report.

Publication of this report does not constitute final Air Force recommendations of the report's findings or conclusions, but it does represent a source for stimulation of advanced control-display ideas.

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ABSTRACT

The "Integrated Information Presentation and Control System Study" (IIPACS-1), Volumes I and II, Air Force Flight Dynamics Laboratory report AFFDL-TR-70-79, describes three cockpit concepts developed to significantly reduce workload for the tactical fighter pilots of the 1980's.

The wraparound cockpit of the IIPACS-1 was selected as the baseline configuration for systematic degraded mode analyses. The cockpit concept was evaluated subjectively and by means of a computerized workload analysis. The results of the analyses and evaluations, conducted to determine the control and display requirements for contingency operations, are reported in this document, AFFDL-TR-70-79, Volume III.

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I. INTRODUCTION

A great number of sophisticated controls and displays will be available for inclusion in aircraft of the 1980's. The Integrated Information and Control System Study (IIPACS-1) offers a means for minimizing the 1980 tactical fighter man-machine interface problem for normal operations. Contingency operations present additional system and control/display problems.

Consistent with the IIPACS-1 study, the requirement for a systems approach to totally integrate the man-machine system during normal and degraded mode operations became evident. The end product of a degraded mode analysis is to provide the capability to safely continue operations after sustaining failures to an identifiable level.

II. STUDY METHOD

The IIPACS degraded mode analysis was conducted within the constraints of the ground rules and assumptions described in Volume I, "Integrated Information Presentation and Control Systems Study - System Development Concepts." The study was divided into four phases: (1) Degraded Mode Survey, (2) Degraded Mode Analysis and Design, (3) Mockup and Evaluation, and (4) Documentation. The activities of each phase are depicted in the IIPACS-2 program flow chart, Figure 1. Each activity found in the flow chart is amplified in the following paragraphs.

1. PHASE I--DEGRADED MODE SURVEY

The purpose of the Degraded Mode Survey phase is to provide a basis for and a selection of the anomalies to be analyzed. This phase is comprised of three elements: (1) reliability survey, (2) data acquisition, and (3) failure mode selection.

RELIABILITY SURVEY--During the visits to military and industrial facilities to obtain 1980 state-of-the-art information (Appendix 2, Volume I), projected mean-time-to-failure (reliability) figures were obtained. In general, the reliability of 1980 avionic equipment is expected to improve as solid-state technology is advanced.

DATA ACQUISITION--A Field Experience Program, initiated by The Boeing Company in 1964, provided a source of current reliability information. The program (1) utilizes quantitative data from Air Force AFM 66-1 and Navy Maintenance and Materiel Management (3M) systems, (2) supplements these data with qualitative information from field surveys, (3) documents both products, and (4) applies the findings to research and design activities. The data bank includes failures due to battle damage, personnel induced failures, and material failures.

FAILURE MODE SELECTION--A list of systems and subsystems, defined in the IIPACS INTERFACE DIAGRAM contained in the envelope on the back cover of Volume I, was drawn. Each system and subsystem was examined in every flight phase for its impact upon safety of flight or mission completion. The results of this analysis, Appendix 1, lists those systems selected as failure modes. Critical systems were faulted without regard to failure probabilities since, ultimately, the anomaly could be caused by battle damage.

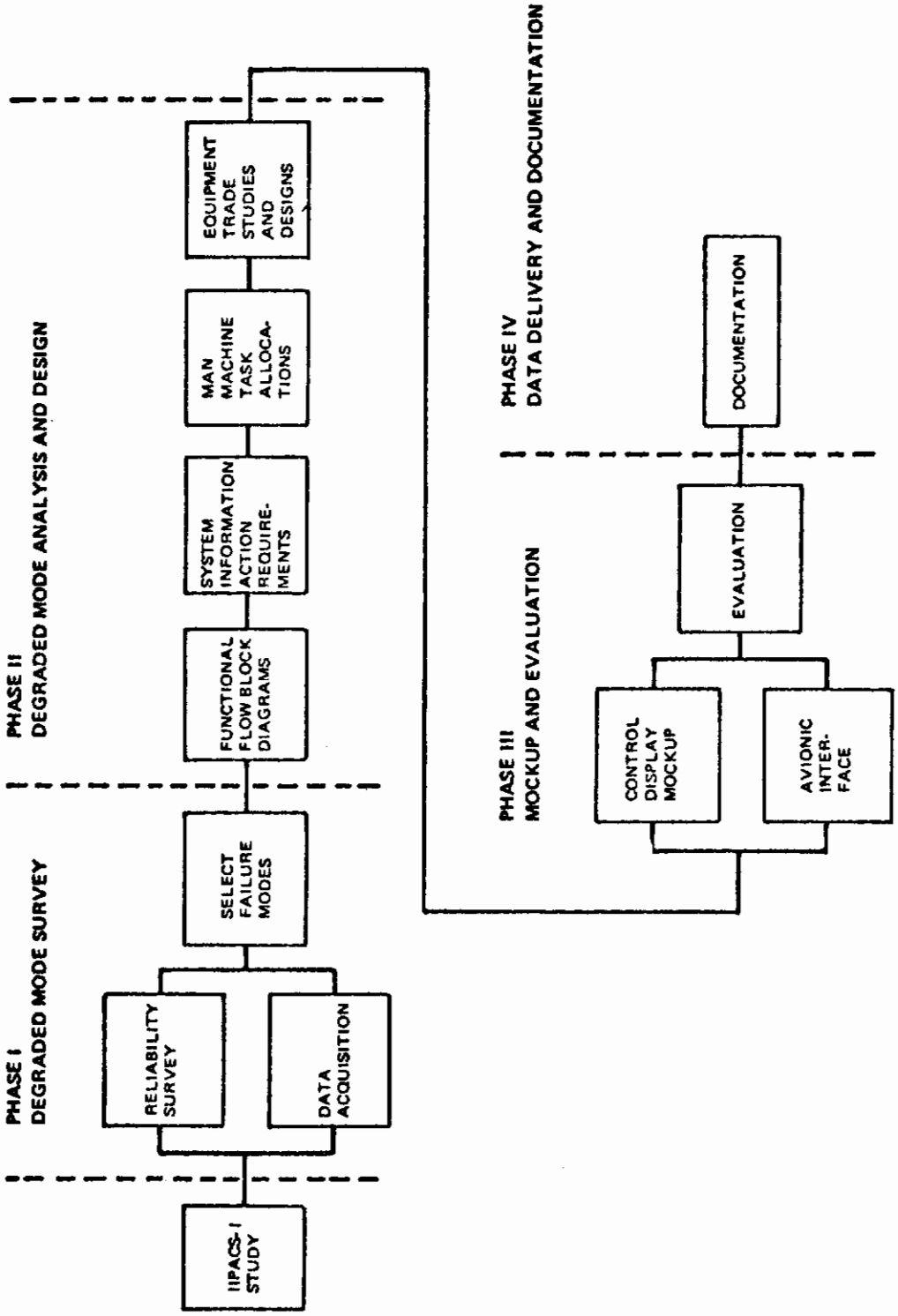


Figure 1. IIPACS-2 Program Flow Chart

2. PHASE II--DEGRADED MODE ANALYSIS AND DESIGN

A degraded mode analysis was conducted to determine the effect of the selected failure modes upon the IIPACS configuration. Functional flow block diagrams were developed to depict the series of events and the effects resulting from the anomaly. System information and action requirements and task allocations provided a basis for equipment selected for a trade study and the subsequent design.

FUNCTIONAL FLOW BLOCK DIAGRAMS--Functional flow block diagrams were constructed with consideration to failure effects. The options available, after the anomaly is assumed to have occurred, are presented in the flow diagrams.

The flow diagrams are related by reference block to those developed in the IIPACS-1 study, Volume II, and are numbered accordingly.

SYSTEM INFORMATION AND ACTION REQUIREMENTS--The functions defined by the flow diagrams were reduced to the next level of indenture--tasks. The actions required to perform the functions were identified. The information necessary to the performance of the action task was listed.

MAN/MACHINE TASK ALLOCATIONS--The action and information requirements are system oriented. At this juncture, the division of responsibility for the physical performance of the task by man or machine is made. Based upon the level of automation established in Volumes I and II, and the capabilities unique to man and machine, the task allocations were made.

EQUIPMENT TRADE STUDIES AND DESIGNS--Since the contingency modes selected are critical to either safety of flight or mission completion, all tasks allocated to the pilot were considered vital. As such, associated equipment was placed in its respective primary reach or vision envelope. These envelopes are described in Volume I.

Pilot task requirements were examined and methods for implementing the pilot's action were defined. Human factor pros and cons relating to each method chosen were listed and evaluated. The equipment offering the most promising performance in terms of pilot performance was selected for inclusion in the cockpit.

In the more obvious cases, equipment selection for degraded mode operations was included in the system description (see Volume I). The description of the computer and the navigation systems are classic examples of this approach.

3. PHASE III--MOCKUP AND EVALUATION

CONTROL DISPLAY MOCKUP--The full-scale cockpit mockup fabricated for the IIPACS-1 study was modified to reflect the results of the degraded mode analysis. In addition, the modifications to the control and display representations include the results of updating the system's technology.

IIPACS INTERFACE DRAWING--The IIPACS-1 interface drawing has been updated and the format modified for clarity. The interface drawing, depicting system relationships, is divided into four sections: (1) Aircraft Systems, (2) Central Computer Complex, (3) Displays, and (4) Controls.

The interface drawing identifies hardware oriented systems but points to the necessitv for identifying systems in a functional sense.

4. COMPUTERIZED WORKLOAD EVALUATION

Historically, a method for analytically determining crew workload has been difficult to achieve due to the complex relationships that exist between man's sensors (visual, auditory), intellectual functions, and his actions (hands, feet, voice). While these relationships are not completely understood, a computerized procedure has been developed by The Boeing Company that attempts to account for these interactions. This procedure, identified as the model for Workload Evaluation for Cockpit Crews (WECC), is based on the principle that an operator performs the functions of seeing, hearing, physical movement, etc. simultaneously in accomplishing a single task. In addition, some functions or sensory channels may be operating throughout the total task execution time while others are involved less or not at all.

The purpose of this evaluation is to determine the effects of contingency operations upon pilot workload. The evaluation is analytical in nature and involves the combining of pilot tasks, performance times, and aircraft operating procedures. Workload percentage factors were produced based upon the ratio of time required to perform tasks to the actual operating time available. Outputs from the computer model furnished pilot workload quantitative assessments for use in engineering analyses.

The IIPACS-1 cockpit was reconfigured to reflect the results of the degraded mode analysis. The mission profile was examined to select the segments into which anomalies were introduced to produce a "worst case" situation. Based on hazard to safety, impact on mission completion, and the number of system tasks required, the following anomalies were assumed during the low-level penetration segment of the air-to-ground combat phase of the mission:

- Engine failure
- Automatic terrain-following failure
- Navigation satellite failure
- Electrical distribution failure

The procedure for conducting the workload analysis is shown in Figure 2. Supporting data for the computerized workload evaluation is contained in Appendix II.

For each selected phase, a list of the operator tasks required to complete that phase was developed. The tasks were sequenced. Completion times were assigned based

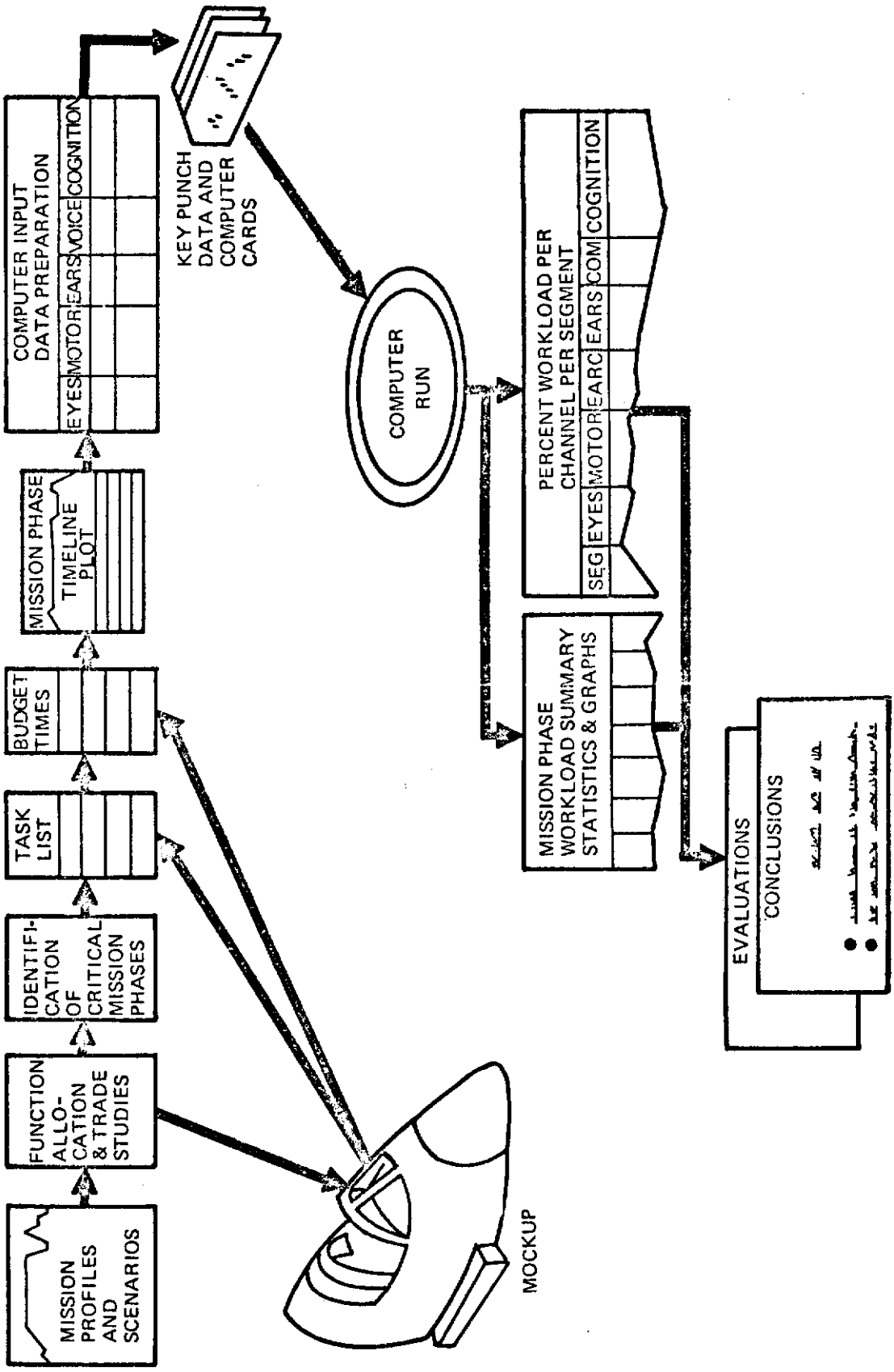


Figure 2. Crew-Workload Evaluation Method

on data obtained from Reference 1. This information was summarized on mission timeline plots to provide an overview of each phase and the data prepared for computer processing. The timeline plots for each phase are contained in Appendix II.

Channels considered in this analysis were visual (external/internal), motor/manual (left hand, right hand, feet), cognitive, and auditory/verbal. These channels constitute sensors, mental processing, and responders used to perform the various tasks identified. To determine the channel operating times, three parameters are specified for each task: (1) the task type, (2) the applicable channels, and (3) the total task completion time. Each task was classified according to whether it was a discrete, monitor, or continuous activity. The task categories are defined as follows:

Discrete	--Single-action task effecting change in system status
Monitor	--Intermittent checking of system status
Continuous	--Continuous action task effecting change in, or maintaining system status.

Determination of applicable channels for each task was based on an examination of the task performance characteristics and the mockup control/display layout. The time-per-channel budgeted to a particular task varied in percentage of total execution time according to task classification and the channel involved (Table I). If two or more overlapping tasks required reference to the same visual display, the visual load was assumed to be time-shared.

A subroutine of WECC was used to determine the channel time-in-use for each task (based on type and applicable channels) and to provide a summary of total channel time-in-use for each segment within a phase. The channel time-in-use summaries for each segment constituted the basic data upon which the computer calculates the workload statistics for that phase.

Table I. Channel Time-In-Use Distributions

	Task Classification		
Sensory Channel	Discrete (%)	Monitor (%)	Continuous (%)
External vision	50	100	100
Internal vision	50	100	100
Left hand	100	80	100
Right hand	100	80	100
Feet	100	80	100
Cognition	25	40	45
Auditory	40	40	45
Verbal	40	80	45

Computer Data Processing

The technical details of the computer program are reported in Reference 2. In general, channel workload, W_c, is defined as:

W_c = total time the channel was used for each 30-second segment. A channel constant, Y_c, is also defined as:

$$Y_c = \frac{1}{30 \text{ seconds per segment}} = 0.0333 \text{ segment per second}$$

The resulting workload percentage, R_c, is the product $R_c = 100.W_c.Y_c$ percent. For example, if the internal vision channel was used for six seconds during some segment, then $W_c = 6$, $Y_c = 0.0333$, and $R_c = 20$ percent workloading. If any R_c has a value near 100 percent, then a critical workload exists for that segment.

To provide additional information concerning the operator's workload, four additional measures are computed for each segment: total visual, total motor, total communication, and a weighted average of all channels. Designating the eight original sensor channels (Table I) by R_1 through R_8, the total vision is given by:

$$R_9 = R_1 + R_2;$$

total motor is:

$$R_{10} = \frac{R_3 + R_4 + R_5}{3}$$

and total communication is:

$$R_{11} = R_7 + R_8.$$

The weighted average is given by:

$$R_{12} = \frac{\frac{R_1 + R_2}{2} + R_3 + R_4 + R_5 + R_6 + \frac{R_7 + R_8}{2}}{6}$$

Then the information for each of the segments is combined to provide a workload estimate for the entire phase. This estimate consists of the mean and standard deviation for each channel for the phase. These statistics are computed as follows:

Let N be the number of 30-second segments in the phase. The workload sum is then defined as:

$$S_{\substack{k \\ K=1,12}} = \sum_{i=1}^{N} W_{cik}$$

where:

W_{ci} is the channel workload in each of the k channels. The sum of the squares

$$SS_k = \sum_{i=1}^{N} (W_{cik})^2$$

the average phase workload

$$A_k = \frac{S_k}{N}$$

the standard deviation

$$SD_k = \sqrt{\frac{N.SS_k - (S_k)^2}{N(N-1)}}$$

and the variance

$$V_k = (SD_k)^2.$$

Computer Output

The workload data processed by the computer results in two types of outputs: (1) listed statistics, and (2) graphic summaries.

The listed statistics are provided in two sets. The first contains the percent loading for each of the eight sensory channels and the four combined measures for each segment by mission phase. The second contains the phase summary statistics, and consists of the mean and the standard deviation (σ) values for each channel.

The graphic outputs consist of the mean plus one standard deviation for each channel along with the 50th, 84th, and 100th percentile for each phase. The results for the phases analyzed in this study are presented below.

Results

The results of this evaluation consist of the pilot workload percentages for each anomaly investigated. The tabulated statistics are contained in Appendix II, while a graphic overview of the workload situation is shown in Figure 3. As can be seen, the weighted average workload imposed by the anomalies appear as spikes that exceeded 40 percent in only one instant--automatic terrain-following failure.

Workload is greatest in the area of vision during normal operations. This is due to a highly automated system in which the pilot's major role is that of monitor. Noteworthy is the fact that workload in the area of vision is reduced during degraded mode operations. This is because normal operations are deferred during the anomaly, and the pilot is engaged in those tasks necessary to survival or mission completion.

An indication of the amount that each of the channels onntributed to the overall workload is given in Appendix III. It will be seen that for all three phases, the visual channel has the highest loadings followed by cognition. The motor and verbal channels show little activity. A more detailed breakdown (internal/external vision, left/right hand, etc.) will also be found in Appendix III.

The high levels of loading for the visual and cognitive tasks, and the low loading for motor activities reflect the high degree of automation achieved during this program. The pilot functions primarily as a systems manager with the equipment performing the majority of the actual operations. These results also show, however, that automation can result in high workloads in some areas such

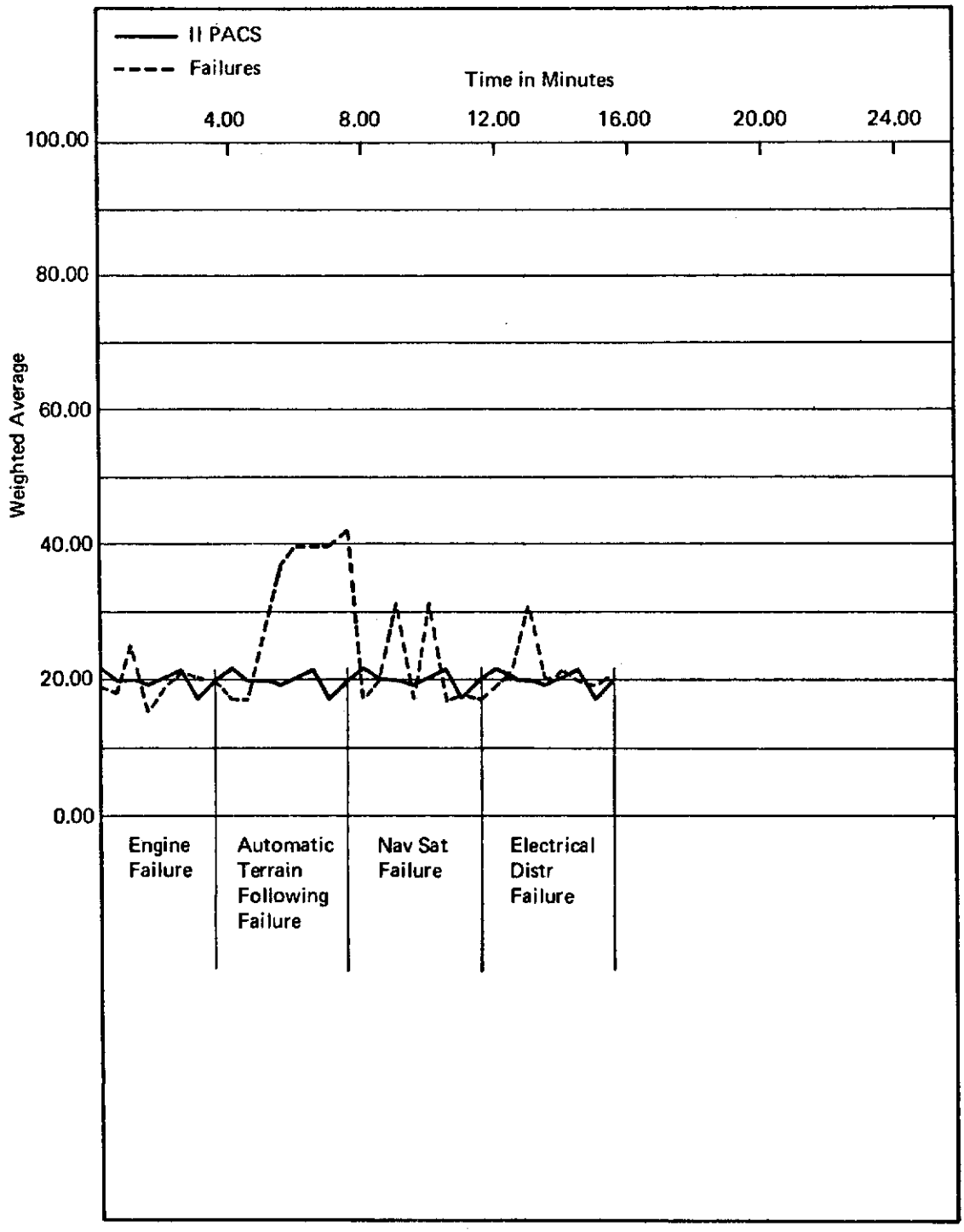


Figure 3. Workload Summary

as vision. Since these phases were selected for analysis on the basis of their complexity, they represent worst-case situations and the workloads for the other phases would be proportionately lower. From this analysis, it appears that the pilot of an IIPACS configured aircraft would be able to cope with contingencies.

CONCLUSIONS

The wraparound cockpit of the IIPACS-1 tactical fighter weapon system provided the baseline configuration for the degraded mode analysis. The study results provided control and display modifications and additions designed to permit a high degree of survivability and mission completion after sustaining failures to an identifiable level.

Specific conclusions are:

- The IIPACS concept, updated in response to advancing technology, offers a significant advance in tactical weapon system effectiveness.
- That through a dependent system of automation, a reduction of pilot workload will be realized.
- That time-sharing techniques, multipurpose controls and displays and integration of information and control functions is feasible.
- Workload per unit of time during anomalies may well drop below that of normal operations. This is because the pilot defers normal operations during contingency situations. This was borne out by the degraded mode workload evaluation and verified in film reviews of A6 emergency operations.
- The controls and displays developed as a result of the degraded mode analysis will permit contingency operations without an overburdening pilot workload.

APPENDIX I

SELECTED FAILURES

2.1.1.2/3 START & PREFLIGHT CHECKOUT

SAFETY OF FLIGHT	MISSION CRITICAL
APU	
Fire	
PROPULSION	PROPULSION
Engine Fire	Reduced Thrust
Engine Loss	
ELECTRICAL	ELECTRICAL
Electrical Fire	AC Power
	DC Power
	STORES MANAGEMENT
	SLU
	CLU
	Armament
	LANDING GEAR
	Tires
	Brakes
	Steering
	Arresting
	AERODYNAMIC CONTROL
	Flight Control
	High Lift
	Wing Sweep
	Thrust Reverser
	ENVIRONMENTAL CONTROL
	Contamination
	Temperature
	Ice Control
	FUEL
	Transfer
	Indicating

2.1.1.2/3 START & PREFLIGHT CHECKOUT (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	NAVIGATION
	INS
	Satellite
	HARS
	Radio Altimeter
	TACAN
	Sta Keep
	Collision Avoidance
	AUTOMATIC FLIGHT CONTROL
	Autopilot
	SAS
	Variable Stability
FMAC	
Caution & Warning	
	ITEMS
	CONTROLS AND DISPLAYS
	Primary Flight Control
	Throttle Control
	HUD/VSD
	MPD's
	HSD/Map
	ESCAPE SYSTEM
	Crew Module
	Emergency Life Support
	CCC
	COMM/IDENT
	Spread Spectrum
	Voice
	D/L
	Satellite
	IFF transponder
	IFF interrogator
	Intercom
	Mixer

2.1.1.2/3 START & PREFLIGHT CHECKOUT (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	FIRE CONTROL
	LLLTV/FLIR
	LASER Ranging
	MMR
	TF/TA
	GM/Search
	GM/Squint
	Spotlight or Snapshot
	MTI
	HTT
	A/A Search/Track
	Dogfight
	AGR
	PENETRATION AIDS
	RHAW
	IR Warning
	RF Jamming/Deception
	IR Jammer
	Chaff/Flare Dispensing
	ECM Blanking
	LIGHTING
	Interior
	FIRE DETECTION
	HYDRAULICS
	Primary
	Utility
	PNEUMATIC

2.1.1 TAXI AND TAKEOFF

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
STORES MANAGEMENT	
Armament	
LANDING GEAR	
Tires	
Brakes	
Steering (Includes Auto)	
AERODYNAMIC CONTROL	
Flight Control	
High Lift	
Wing Sweep	
Thrust Reverser	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Temperature
	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	TACAN
	Station Keep
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
	Variable Stability
FMAC	
Warning & Caution	
ITEMS	

2.1.1 TAXI AND TAKEOFF (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map
CENTRAL COMPUTER COMPLEX	
	COMM/IDENT
	Spread Spectrum
	Voice
	IFF Transponder
	FIRE CONTROL
	FLIR
	LIGHTING
	Interior

2.1.2 CLIMB

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROLS	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Temperature
	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Satellite
	TACAN
	Station Keep
	Collision Avoidance
AFC	AFC
SAS	Autopilot
	Variable Stability
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map
CCC	

2.1.2 CLIMB (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	COMM/IDENT
	Spread Spectrum
	Voice
	D/L
	IFF Transponder
	FIRE CONTROL
	MMR
	GM--Search
	LIGHTING
	Interior

2.1.3 RENDEZVOUS

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	PROPULSION
Engine Fire	Reduced Thrust
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROL	
Flight Control	
High Lift	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Temperature
	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Satellite
	TACAN
	Station Keep
	Collision Avoidance
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
	Variable Stability
FMAC	
Caution and Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	HSD/Map
	MPD's
CENTRAL COMPUTER COMPLEX	

2.1.3 RENDEZVOUS (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	COMM/IDENT
	Satellite
	Spread Spectrum
	Secure Voice
	Data Link
	IFF Transponder
	FIRE CONTROL
	MMR
	GM--Search

2.1.4 CRUISE

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
	STORES MANAGEMENT
	CLU
	SLU
	Armament
AERODYNAMIC CONTROL	
Flight Controls	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Temperature
	Pressurization
FUEL	
Transfer	
NAVIGATION	NAVIGATION
INS	Satellite
	Collision Avoidance
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Variable Stability
FMAC	
Caution & Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map

2.1.4 CRUISE (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
CCC	COMM/IDENT Satellite Spread Spectrum Secure Voice Data Link IFF Transponder IFF Interrogator FIRE CONTROL MMR GM--Search PENETRATION AIDS RHAW IR Warning

2.2.2 LOITER

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	PROPULSION
Engine Fire	Reduced Thrust
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
	STORES MANAGEMENT
	SLU
	CLU
	Armament
AERODYNAMICS CONTROL	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Ice Control
FUEL	
Transfer	
NAVIGATION	NAVIGATION
INS	Satellite
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Variable Stability
FMAC	
Caution & Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map
CCC	

2.2.2 LOITER (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	COMM/IDENT Satellite Spread Spectrum Voice D/L IFF Transponder IFF Interrogator FIRE CONTROL MMR GM--Search A/A Search/Track PENETRATION AIDS RHAW IR Warning (360°)

2.2.4 AIR-TO-AIR COMBAT

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
	STORES MANAGEMENT
	CLU
	SLU
	PAL
	Armament
AERODYNAMIC CONTROL	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Temperature
	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	
INS	
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
	Variable Stability
FMAC	
Caution & Warning	
ITEMS	

2.2.4 AIR-TO-AIR COMBAT (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	Designation Control
Throttle Control	HUD/VSD
	HSD
	MPD's
CENTRAL COMPUTER COMPLEX	
	COMM/IDENT
	Satellite
	Spread Spectrum
	Voice--Secure
	Data Link
	IFF Transponder
	IFF Interrogator
	FIRE CONTROL
	MMR
	A/A Search/Track
	Dogfight
	PENETRATION AIDS
	RHAW
	RF Jamming/Deception
	IR Warning (360°)
	IR Jammer (Tail)
	Chaff/Flare Dispensing
	ECM Blanking

2.2.5 REFUEL

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	PROPULSION
Engine Fire	Reduced Thrust
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROL	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Ice Control
	Pressurization
FUEL	FUEL
Transfer	Indicating
Vent and Pressurization	
NAVIGATION	NAVIGATION
INS	TACAN
	Station Keep
	Satellite
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Variable Stability
FMAC	
Caution & Warning	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	HSD/Map
	MPD's
	Designation Control
CCC	

2.2.5 REFUEL (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	COMM/IDENT
	Satellite
	Spread Spectrum
	Voice
	FIRE CONTROL
	FLIR
	LASER Ranging
	MMR
	A/A Search/Track
	BCN
	PENETRATION AIDS
	RHAW
	IR Warning

2.2.1 DESCEND FOR A/G COMBAT--PENETRATION

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROL	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Satellite
	Radio Altimeter
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
	Variable Stability
FMAC	
Caution & Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Flight Control	HUD/VSD
Throttle Control	HSD/Map
	MPD's
CCC	
	COMM/IDENT
	Satellite
	Spread Spectrum
	Voice
	D/L
	IFF Transponder
	IFF Interrogator

2.2.1 DESCEND FOR A/G COMBAT--PENETRATION (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
	FIRE CONTROL FLIR MMR TF/TA GM--Search GM--Squint PENETRATION AIDS RHAW RF Jamming/Deception IR Warning (360°) IR Jamming Chaff/Flare Dispensing ECM Blanking

2.2.3 AIR-TO-GROUND COMBAT--PENETRATE

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
	STORES MANAGEMENT
	CLU
	SLU
	PAL
	Armament
AERODYNAMIC CONTROL	
Flight Control	
Wing Sweep	
ENVIRONMENTAL CONTROL	
Contamination	
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Satellite
	Radio Altimeter
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
Autopilot	Variable Stability
SAS	
FMAC	
Caution & Warning	
ITEMS	

2.2.3 AIR-TO-GROUND COMBAT--PENETRATE (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	Designation Control
Throttle Control	HUD/VSD
	HSD/Map
	MPD's
CCC	
	COMM/IDENT
	Satellite
	Spread Spectrum
	Voice
	D/L
	IFF Transponder
	IFF Interrogator
	FIRE CONTROL
	FLIR
	MMR
	TF/TA
	GM--Search
	GM--Squint
	Snapshot
	ECCM
	PENETRATION AIDS
	RHAW
	RF Jamming/Deception
	IR Warning
	IR Jamming
	Chaff/Flare Dispensing
	ECM Blanking

2.2.3 AIR-TO-GROUND COMBAT (ATTACK)

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
Reduced Thrust	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
	STORES MANAGEMENT
	CLU
	SLU
	PAL
	Armament
AERODYNAMIC CONTROL	AERODYNAMIC CONTROL
Flight Control	Direct Lift
Wing Sweep	
ENVIRONMENTAL CONTROL	ENVIRONMENTAL CONTROL
Contamination	Ice Control
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Satellite
	Radio Altimeter
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
	Variable Stability
FMAC	
Caution & Warning	
ITEMS	

2.2.3 AIR-TO-GROUND COMBAT (ATTACK) (Cont)

SAFETY OF FLIGHT	MISSION CRITICAL
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	Designation Control
Throttle Control	HUD/VSD
	MPD's
	HSD/Map
CCC	
	COMM/IDENT
	Satellite
	Spread Spectrum
	Voice
	D/L
	IFF Transponder
	IFF Interrogator
	FIRE CONTROL
	LLLTV/FLIR
	LASER Ranging
	MMR
	TF/TA
	MTI
	HTT
	Spotlight
	GM--Search
	PENETRATION AIDS
	RHAW
	RF Jamming/Deception
	IR Warning (360°)
	IR Jamming (Tail)
	Chaff/Flare Dispensing
	ECM Blanking

SAFETY OF FLIGHT	MISSION CRITICAL
	BATTLE DAMAGE ASSESSMENT Video Recording LLLTV/FLIR MMR Data Recording

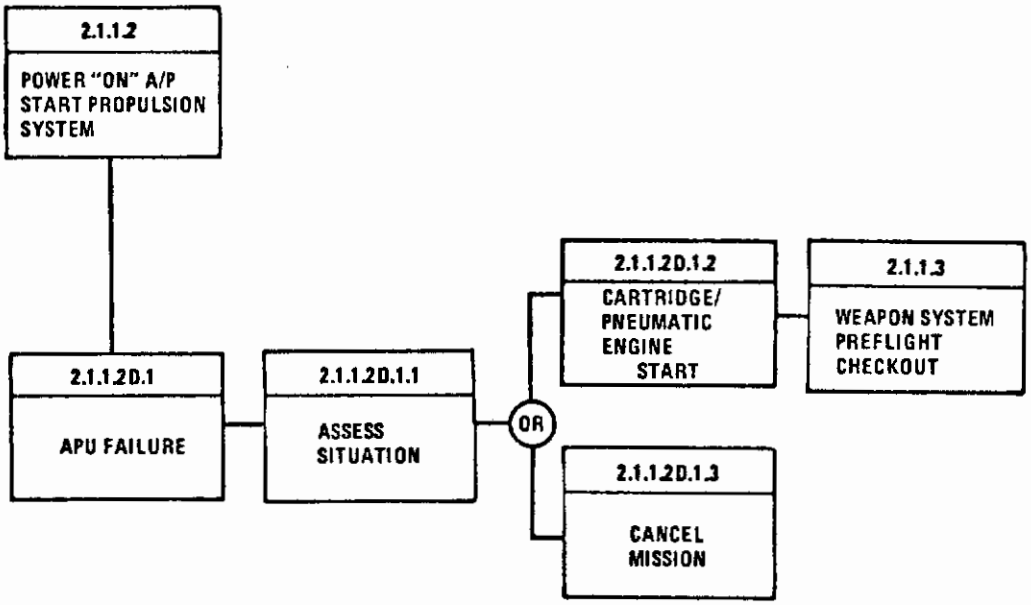
2.2.3 DESCEND FOR LANDING

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROL	AERODYNAMIC CONTROL
Flight Control	High Lift
Wing Sweep	
FUEL	FUEL
Transfer	Indicating
NAVIGATION	
INS	
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Variable Stability
FMAC	
Caution & Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map
CCC	
	COMM/IDENT
	Spread Spectrum
	Voice
	IFF Transponder

2.3.4/5 APPROACH AND LAND

SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
LANDING GEAR	
Tires	
Brakes	
Steering	
AERODYNAMIC CONTROLS	AERODYNAMIC CONTROLS
Flight Control	Direct Lift
High Lift	
Wing Sweep	
ENVIRONMENTAL CONTROL	
Contamination	
FUEL	FUEL
Transfer	Indicating
NAVIGATION	NAVIGATION
INS	Precision ILS
	Radio Altimeter
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Autopilot
FMAC	
Caution & Warning	
ITEMS	
CONTROLS AND DISPLAYS	CONTROLS AND DISPLAYS
Primary Flight Control	HUD/VSD
Throttle Control	MPD's
	HSD/Map
CCC	

SAFETY OF FLIGHT	MISSION CRITICAL
	COMM/IDENT Spread Spectrum Voice D/L IFF Transponder FIRE CONTROL MMR GM--Search



ASSUMPTIONS:

1. APU IS JET ENGINE STARTER (AIRESEARCH OR EQUIV) WITH ALTERNATE CAPABILITY TO DRIVE ACCESSORIES
2. APU IS MOUNTED ON ONE ENGINE
3. CARTRIDGE/PNEUMATIC STARTER MOUNTED ON 2ND ENGINE
4. STARTER CARTRIDGE IS CARRIED IN BREECH ON 2ND ENGINE
5. EITHER ENGINE MAY BE STARTED BY CROSS BLEED
6. CCC & CITS ENERGIZED PRIOR TO START

Figure 4. APU Failure

Degraded Mode: **APU FAILURE DURING ENGINE START**

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.1.2 Power on Aircraft Start Propulsion Sys												
2.1.1.2D.1 APU Failure		1. Detect APU failure.	1. FMAC ~~xxxxx~~ fault					Ref. 2.1.1.6 "Communicate"	5.0	Machine	Note: FMAC operates on battery power – same as CCC and one of the MPD's.	
		2. Warn crew.	2. APU fault elect. and/or mechanical	MPD					5.0	Machine		
		3. Monitor instructions.	3. Preprogrammed msg. in storage	MPD	(Storage)	TNC	2.0	"	5.0	Man		
	2.1.1.2D.1.1 Assess Situation	1. Consider: FMAC instructions						"	5.0			
		Elect./mech. problem only – no fire present						"	5.0			
		Mission importance						"	5.0			
		2. Decision – Select alternate start method. Note: If not loaded with cartridge starters, allow 60 sec. for loading.				TNC	2.0	"	5.0	Man		
	2.1.1.2D.1.2 Cartridge/Pneumatic Engine Start	1. Battery "on."	1. Battery available		Elect. Cont. Panel	TNC	1.5	"	5.0	Man	Require: Battery switch.	See "Elect Cont Panel"
		2. Select engine master switch – selected engine for start.	2. Left engine switch to "on."		Engine Start Panel	TNC	1.5	"	5.0	Man		
		3. Engine start switch to "cartridge start."	3. Left engine "cartridge start" selection		Engine Start Panel	TNC	1.5	"	5.0	Man	Require: Redesign of control control required to provide ~~alt~~ start capability.	See "Elect Cont Panel"
		4. Initiate starter cartridge/pneumatic.	4. Cartridge starter available					"	5.0	Machine	Note: Electric power for starting and monitoring engine parameters is supplied by battery. Power is provided to CITS, CCC keyboard, and one MPD.	
		5. Select "run" position.	5. Throttle position		Engine Start Panel	TNC	1.5	"	5.0			
		6. Sense engine parameters.	6. RPM, TIT, EPR, Oil P., FF					"	5.0	Machine		
		7. Monitor engine parameters.	7. (Same as above.)	MPD		TNC	20.0	"	5.0	Man/Machine		
		8. Select engine master 2nd engine start.	8. Right engine switch to "on."		Engine Start Panel	TNC	1.5					
		9. Cross bleed "open."	9. Left and right engine bleed					"	5.0	Machine		
		10. Disable 2nd engine cartridge initiator.	10. Cartridge disabled					"	5.0	Machine		
		11. Engine start switch to "start" on 2nd engine.	11. Right engine "start."			TNC	1.5	"	5.0	Man		
		12. Sense engine parameters.	12. RPM, TIT, EPR, Oil P., FF					"	5.0	Machine		
		13. Monitor engine parameters.	13. (Same as above.)	MPD	Engine Start Panel	TNC	20.0	"	5.0	Man		
Ref. 2.1.1.3 Weapon System Preflight Checkout												
	or											
	2.1.1.2D.1.3 Cancel Mission	1. APU operate switch "off."		L. Console	L. Console	TNC	1.2					
		2. Battery switch "off."		L. Console	L. Console	TNC	1.2					
		3. Exit aircraft.				TNC	15.0					

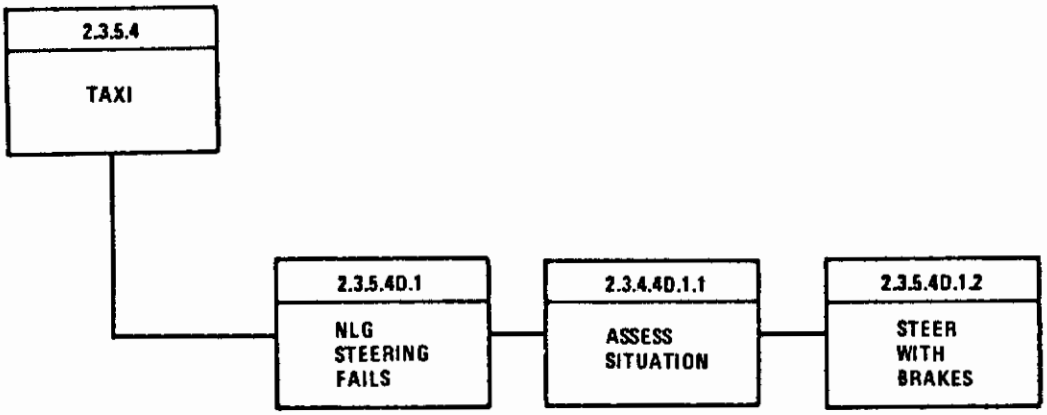


Figure 5. NLG Steering Failure

Degraded Mode: NOSE LANDING GEAR STEERING FAILURE - TAXI

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.3.5.4 Taxi												
2.3.5.4D.1 NLG Steering Fails During Taxi		1. Detect failure.	1. Fault exists					Ref. 2.3.5.4 "Taxi" Vol. II		Machine		
		2. Warn crew.	2. Warning message in storage, voice tactile	Master Caution Voice, Hud/VSD						Machine	Require voice, visual and tactile warning on all systems which effect safety of flight.	
		3. Monitor warning and procedures.	3. Preprogrammed instructions to crew.	MPD	(Storage	2.0	2.0	" "	1.0	Man		
		4. Communicate and inform.	4. Radios available	MPD	Comm./Ident. Panel	TNC	3.0	" "		Man/Machine		
	2.3.4.4D.1.1 Assess Malfunction	1. Check manual steer.		MPD	Rudder Pedals	2.0	2.0	" "	2.0	Man		
		2. Consider FMAC instructions.		MPD		(Included in (3) above)		" "	2.0			
		3. Decision				2.0	1.0	" "	2.0	Man		
	2.3.5.4D.1.2 Steer with Brakes	1. Sense directional information.	1. Steering direction					" "		Machine		
		2. Present steering information.	2. Steering cues	VSD/HUD/MPD				" "		Machine		
		3. Monitor ground track.	3. Visual cues/heading scale	VSD/HUD/MPD		Continuous		" "	2.0	Man		
		4. Apply brake(s) as required to alter heading.	4. Brake steering available		Brake Pedal (s)	2.0	1.0	" "	2.0	Man		
		5. Apply opposite brake to stop turn.	5. (Same as (4) above.)		Brake Pedal (s)	2.0	1.0	" "	2.0	Man		

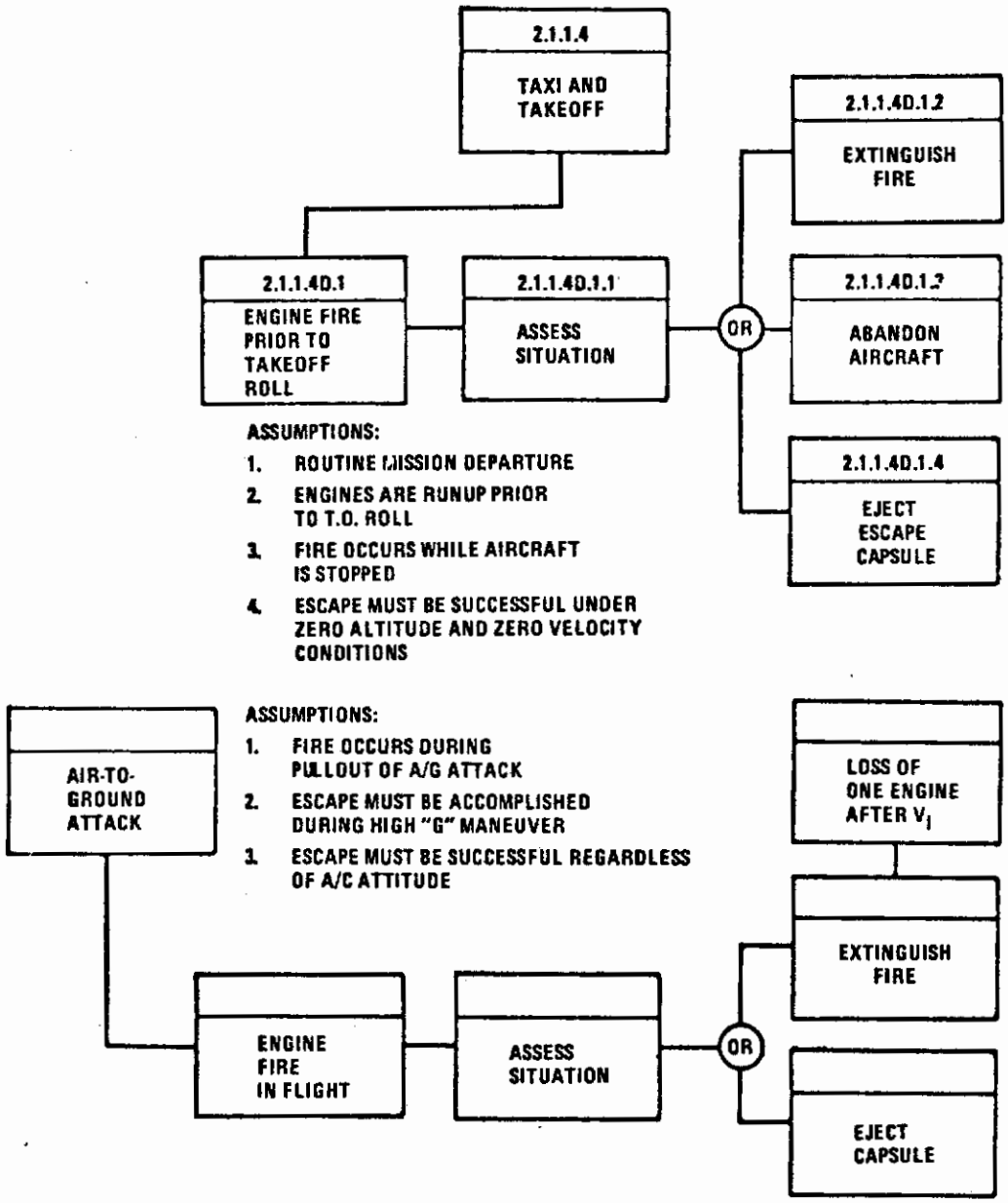


Figure 6. Engine Fire

Degraded Mode: ENGINE FIRE - TAXI

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.1.4 Taxi and Takeoff												
2.1.1.4D.1 Engine Fire Prior to Takeoff Roll	2.1.1.4D.1.1 Assess Trouble	1. Detect fire.	1. Fire or overheat exists.					Ref. 2.1.1.5 "Monitor & Control A/C"		Machine		
		2. Present information.	2. Visual, auditory, tactile	NO						Machine	Fire warning display (see trade study attached).	Red flashing light in primary vision area with auditory warning and readout on MPD
		3. Monitor location.	3. Device shows approx. fire location	Voice/MPD		2.0	2.0	" "	2.0	Man/Machine		
		4. Communicate and inform.	4. Radios avail. (voice & D/L).	MPD	Comm./Ident. Panel & Mic.	5.0	4.0	" "	2.0	Man/Machine		
	2.1.1.4D.1.2 Extinguish Fire	1. Activate fire extinguisher system.	1. Automatic dispensing of suppressant		No	5.0	1.5	" "	2.0	Machine/Man Veto	Automatic fire extinguishing actuation device which man may veto.	Automatic activation of extinguishing system if man does not veto in 10 seconds.
		2. Monitor presentation.	2. Warning will operate as long as condition exists.			2.0	1.0	" "	2.0	Man		
		3. Shut down effected engine(s).	3. Engine ignition off, fuel cutoff, rpm info.	MPD	L. Console	4.0	3.0	" "	2.0	Man	(See trade study attached.)	
	or 2.1.1.4D.1.3 Abandon Aircraft	1. Determine that fire still exists.	1. Fire warning persists after correction has been taken.			3.0	2.0	Ref.2.1.1.6 "Communicate"	3.0	Man/Machine		
		2. Set brakes.	2. Parking brakes set.		Primary Throttle Control	2.0	1.5	"	3.0	Man		
		3. Open canopy.	3. Canopy control avail. and egress route not blocked.		Canopy Control	2.0	1.5	"	3.0	Man		
		4. Exit seat.	4. Harness, life support and comm. disconnects.		Single Point Restraints	2.0	1.5	"	3.0	Man		
		5. Exit aircraft.	5. Ladder or canopy			10.0	5.0	"	3.0	Man		
	or 2.1.1.4D.1.4 Eject Escape Capsule	1. Determine that fire still exists.	1. Fire warning persists.			6.5	5.0	Ref. 2.1.1.6 "Communicate"	3.0	Man/Machine		
		2. Decision - normal egress route unacceptable.	2. Flames visible and engulf normal egress route.			1.0	1.0		3.0	Man		
		3. Activate escape system.	3. Escape handle available.		No	1.5	1.0	"	3.0	Man	Ejection activation device (see trade study attached).	Tee handle in each arm rest.

Degraded Mode: ENGINE FIRE

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Fire Warning Presentation	OPTION NO. 1 Separate warning light display.	OPTION NO. 2 Warning presented on MPD (A/C symbol on VSD turns red and flashes to alert crew).	OPTION NO. 3 Warning presented on MPD same as Option 2, audio warning accompanies.	SELECTION	
CRITICALITY Highly critical for crew survival. **FREQUENCY OF USE** Seldom **RESPONSE TIME** Immediate **PRECISION REQUIREMENTS** Discard false signals—must be highly reliable. **ENVIRONMENT CONSTRAINTS** Provide warning under all conditions. **LOCATION ALLOCATION** **VISION** Primary **REACH** DNA	Pro: 1. Independent of other systems. 2. Proven system. Con: 1. Requires panel space. 2. Lowest attention-attracting method. 3. Must be in field of vision.	Pro: 1. No additional panel space required. 2. Employs installed warning and displays. Con: 1. Dependent on other systems. 2. Subject to interference. 3. Must be in field of vision.	Pro: 1. No additional panel space required. 2. Provides most positive warning. 3. Need not be visually monitoring display. Con: 1. Requires additional audio signal generation system. 2. Dependent on other systems. 3. Subject to interference.	Option 3 This type system should provide the most positive warning available.	

Degraded Mode: ENGINE FIRE

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS FIRE EXTINGUISHER CONTROL	OPTION NO. 1 "T" HANDLE WITH MECHANICAL ACTUATION OF EXTINGUISHER	OPTION NO. 2 PUSH BUTTON - DUAL PURPOSE INDICATOR.	OPTION NO. 3 AUTOMATIC WITH CREW VETO.	SELECTION	
CRITICALITY Highly critical FREQUENCY OF USE Seldom RESPONSE TIME System response should be immediate. PRECISION REQUIREMENTS Highly reliable ENVIRONMENT CONSTRAINTS Must be usable under "G" loads. LOCATION ALLOCATION VISION REACH Primary	Pro: 1. Simple. 2. Independent system. Con: 1. Requires crew activation. 2. Requires panel space. 3. Too time consuming.	Pro: 1. Actuator is same as warning display. 2. Requires no additional panel space over that required for warning. Con: 1. Requires crew activation. 2. Dependent on other systems. 3. Too time consuming.	Pro: 1. Can activate without crew attention. 2. May be vetoed by crew. 3. No panel space required. 4. Quick reaction. Con: 1. Dependent on other systems. 2. Keyboard entry may be required to cancel or switches may be required. 3. Complex.	Option No. 3 This provides the most positive activation of fire extinguishing system under all circumstances.	

Degraded Mode: ENGINE FIRE

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Escape Activation Device	OPTION NO. 1 "T" handle in each arm rest.	OPTION NO. 2 "D" ring crotch location.	OPTION NO. 3 "D" ring overhead (face curtain).	SELECTION	
				Option 1	
CRITICALITY Highly	Pro: 1. Primary reach area. 2. Safety device part of design. 3. Redundant controls. 4. Positive action required to initiate. 5. Actuation direction perpendicular to "G" forces. 6. Safety flag prevents A/C operation with seat on safe.	Pro: 1. Primary reach area. 2. No new procedure to learn. 3. Positive action required to initiate. 4. Easily reached under positive "G" forces.	Pro: 1. Operates with "G" forces. 2. Positive action required to initiate. 3. Movement to actuate tends to position operator in optimum position for escape.	System provides redundancy. Has safety features that preclude flight with an unarmed seat, and does not have to work against "G" forces to actuate. Not prone to inadvertent actuation.	
FREQUENCY OF USE Infrequent					
RESPONSE TIME Immediate—remain on as long as condition exists.	Con: 1. May be new procedure.	Con: 1. Must be operated against "G" forces. 2. Requires external safety pins. 3. Actuation tends to slump operator. 4. May affect seating comfort.	Con: 1. Overhead reach required against "G" forces. 2. Requires external safety pins.		
PRECISION REQUIREMENTS Must be highly reliable—capable of long term storage.					
ENVIRONMENT CONSTRAINTS Capsule must operate at "0" altitude, "0" speed, High ' q" and High ± "G."					
LOCATION ALLOCATION					
VISION					
REACH Primary					

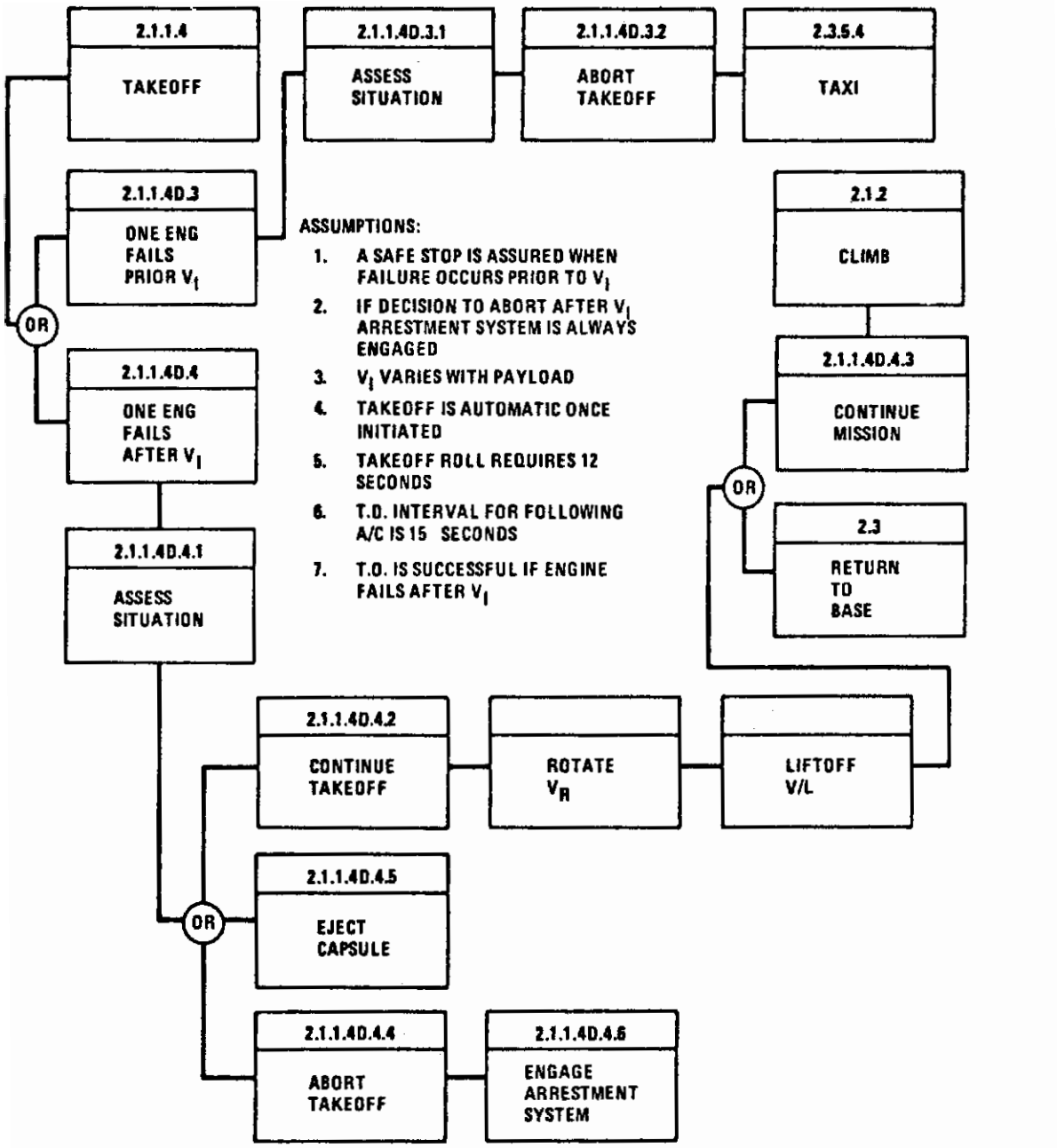


Figure 7. Engine Failure

Degraded Mode: ENGINE FAILURE - TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.1.4 Takeoff												
2.1.1.4D.3 One Engine Fails Prior to V_1		1. Detect failure.	1. Thrust/temp./pressure, speed/V_1/steering	Master Caution Voice, VSD/HUD MPD		12.0 sec. maximum	1.0	Ref. 2.1.1.4, Vol. II "Taxi & Takeoff" Monitor:		Machine		
		2. Warn crew.	2. Visual, auditory and tactile			Included above	2.0	Engine Parameters	1.0	Machine	Tactile/voice and video warning recommended.	
		3. Monitor warning and procedures.	3. Preprogrammed msg. in storage		Comm./Ident. FMAC Listen			Takeoff Parameters	1.0		Note: Present V_1 energy level on items display.	
								Warning Display	1.0	Man	Presentation of warning with recommended action. (See trade study attached.)	
	2.1.1.4D.3.1 Assess Situation	1. Consider: R/W* length required to abort						" "				
		R/W conditions						" "				
		Usable R/W remaining						" "				
		2. Decision - Abort can be accomplished.				Min. - 0 Max. - 12.0	1.0	" "		Man		
	2.1.1.4D.3.2 Abort Takeoff	1. Actuate thrust reverser.	1. Thrust reverser position, power setting		L. Console Throttle			" "		Machine	Require: "Abort" switch to activate itemized 1 thru 4 simultaneously when actuated by pilot (see trade study attached).	Abort switch "Push to Engage" Located in primary reach area near AFCS panel.
		2. Actuate spoilers.	2. Spoiler position		L.Console Throttle (Spoilers/Speed Brakes)			" "		Machine		
		3. Activate wheel brakes.	3. Braking available		Primary Flight Control			" "		Machine		
		4. Actuate arrestment device.	4. Device available		No	(May be tail hook or barrier cutting device)				Machine		
		5. Steer aircraft.	5. Visual/inst. steering cues	MPD	Nose Wheel Steer (Rudders)	Continuous		" "		Man		
		6. Communicate and inform.	6. Radio available (voice)	MPD	Comm./Ident. Panel & Throttle Microphone	5.0	4.0	" "		Man		
		After A/C Comes To Stop										
		1. Reduce power - good engine.		MPD/VSD	L. Console Throttle		1.5	None		Man	"Abort" switch when deactivated returns itemized 1 thru 4 above to normal or retracted position. Engine goes to idle.	Abort switch "Pull to Disengage" (see trade study attached).
		2. Shut down failed engine.		MPD/VSD	L. Console		3.0	None		Man		
		3. Retract thrust reverser.			L. Console Throttle		1.5	None		Man		
		4. Retract spoilers.			L. Console		1.5	None		Man		
		5. Retract arrestment device.			No		1.5	None		Man		
		6. Release wheel brakes.			Primary Flight Control		1.5	None		Man		
Ref. 2.3.5.4 Taxi												

* R/W - Runway

Degraded Mode: ENGINE FAILURE–TAKEOFF

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Abort Switch	OPTION NO. 1 Plunger type on panel.	OPTION NO. 2 Automatic actuation when engine fails.	OPTION NO. 3	SELECTION	
CRITICALITY High FREQUENCY OF USE Infrequent RESPONSE TIME Rapid PRECISION REQUIREMENTS High ENVIRONMENT CONSTRAINTS LOCATION ALLOCATION VISION REACH Primary	Pro: 1. May be actuated at crew's discretion. 2. Man reacts well in contingencies. 3. Simple. 4. Tactile cue eliminates need for display. Con: 1. Requires crew decision. 2. Requires discrete action. 3. Must be manually operated when time is critical. 4. Requires panel space. 5. Must be reset. 6. Requires illumination.	Pro: 1. Will perform function where crew capability is marginal. 2. Can sense small changes in stimuli. 3. Responds rapidly to requirement. Con: 1. Subject to interference. 2. Can execute only as programmed. 3. Must be monitored. 4. Complex and programming required. 5. Requires display.		Option 1 1. Simplicity. 2. Provides positive control. 3. Dicretionary.	

Degraded Mode: ENGINE FAILURE - TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
2.1.1.4D.4 One Engine Fails After V_1		1. Detect failure.	1. Thrust/temp./pressure, speed/V_1/steering	Master Caution, Voice, VSD/HUD MPD				Ref. 2.1.1.6 "Communicate"		Machine		
		2. Warn crew	2. Message in storage (N, voice)			1.0	1.0	"	1.0	Machine	Require: Presentation of warning with recommendation to crew.	Voice and video warning presentation and recommendation.
		3. Monitor warning and procedures.	3. Preprogrammed instructions to crew.		Comm./Ident. (FMAC Listen)	1.0	1.0	"	1.0	Man		
	2.1.1.4D.4.1 Assess Situation	1. Consider: Usable runway remaining; Minimum flying speed						"				
		2. Decision - Takeoff can be made.				1.0	1.0	"		Man		
	2.1.1.4D.4.2 Continue Takeoff	1. Monitor engine parameters.	1. Single engine T.O. and flight data	VSD/HUD/MPD		Continuous		Ref. 2.1.2 "Climb"		Man/Machine		
		2. Monitor T.O. parameters.	2. Speed/V_1/V_R/V_L steering	VSD/HUD/MPD		Continuous		2.1.2.1 "Monitor & Control A/C"				
		3. Rotate aircraft.	3. Speed sufficient for T.O.		Primary Flight Controller							
		4. Monitor single engine flight profile.	4. T.O. and performance data	VSD/HUD/MPD		Continuous		2.1.2.2 "Navigate"				
		5. Shut down failed engine.	5. Engine master switch actuates windmill brake		L. Console	4.0	3.0	" "	2.0	Man		
		6. Communicate with tower.	6. Radios available		Comm./Ident. Panel	TNC	5.0	" "	2.0	Man		
	2.1.1.4D.4.3 Continue Mission	Monitor single engine data and follow squadron doctrine.				TNC		" "		Man		
	2.1.1.4D.4.4 Abort Takeoff	Ref. Analysis Sheet 2.1.1.4D.1.4 "Eject Capsule"										
Ref. 2.1.2 Climb												
Ref. 2.3 Return to Base												

Degraded Mode: ENGINE FAILURE - TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
2.1.1.4D.4 One Engine Fails After V_1 (continued)	2.1.1.4D.4.5 Eject Capsule	Ref. Analysis Sheet 2.1.1.4D.1.4 "Eject Capsule"										
	2.1.1.4D.4.6 Engage Arrestment System	Ref. Analysis Sheet 2.3.5D.1.3 "Emergency Stop Engage Arrestment System"										
		After engagement and aircraft stops:										
		1. Shut down avionics systems.	1. Systems operating - failed and normal	MPD	No	10.0	2.0			Man/Machine	Require: Actuation device for power off avionics bus.	See trade study - Toggle Switch on Electrical Control Panel.
		2. Shut down electrical generating system,	2. Same as above.	MPD	L. Console	TNC	1.5			Man		
		3. Shut down remaining engine.]	3. Same as above.	MPD	L. Console	TNC	3.0			Man		
Ref. 2.3.5.4 Taxi												

Degraded Mode: ENGINE FAILURE—TAKEOFF

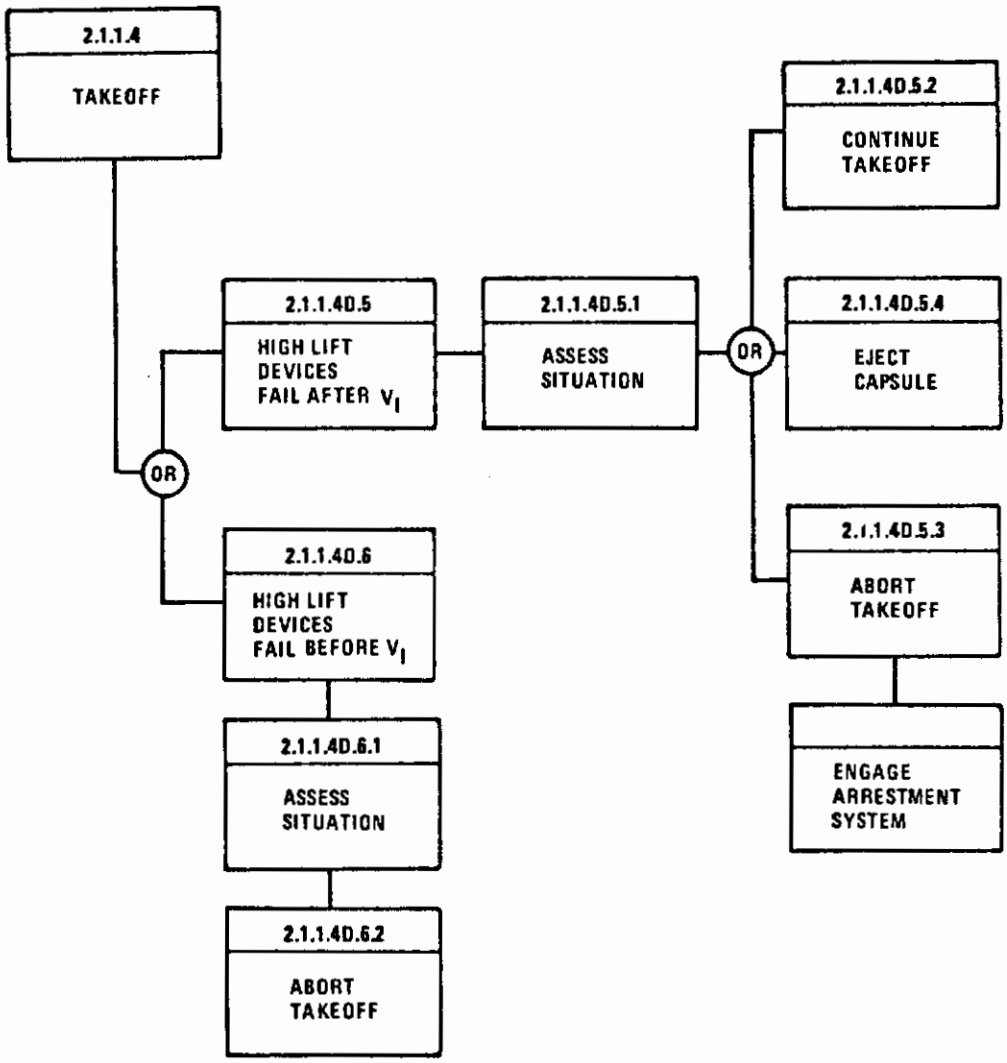
DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Avionics Sequencing Shutdown Control	OPTION NO. 1 Toggle switch on electric panel (momentary).	OPTION NO. 2 Keyboard turn-off function.	OPTION NO. 3	SELECTION	
CRITICALITY Critical to avionics reliability. **FREQUENCY OF USE** Low **RESPONSE TIME** Immediate—normal sequence in 2 seconds prior to electrical system shutdown. **PRECISION REQUIREMENTS** **ENVIRONMENT CONSTRAINTS** **LOCATION ALLOCATION** **VISION** **REACH** Tertiary	Pro: 1. Simple. 2. Rapid actuation. 3. Tactile. 4. Good space factor. 5. Does not require reset. Con: 1. Must be illuminated.	Pro: 1. Does not require additional panel space. 2. Compatible with digital equipment. Con: 1. Complex entry. 2. Time consuming.		Option 1 Provides simple rapid operation.	

Degraded Mode: ENGINE FAILURE—TAKEOFF

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Warning Device(s) (Safety of Flight)	OPTION NO. 1 Warning light and printout on MPD.	OPTION NO. 2 Warning light, printout on MPD, voice warning.	OPTION NO. 3 Warning light, printout on MPD, voice warning, tactile warning.	SELECTION	
CRITICALITY High—requires positive warning and minimum response time. FREQUENCY OF USE Infrequent RESPONSE TIME Immediate—remain on until correction is taken. PRECISION REQUIREMENTS High—no false warning. ENVIRONMENT CONSTRAINTS Must be seen, heard and/or felt in all ambient conditions. LOCATION ALLOCATION VISION Primary REACH	Pro: 1. Simple. 2. Provides recommended action by video. Con: 1. Low attention. 2. Visual cue only provided. 3. Dependent on other systems.	Pro: 1. Provides visual and auditory warning. 2. Redundant. 3. Provides recommended action by audio and video. Con: 1. Medium attention. 2. Dependent on other systems.	Pro: 1. Multiple warning modes. 2. Vision, auditory, and tactile stimuli. 3. Provides recommended action by video and audio. Con: 1. Complex. 2. Dependent on other systems.	Option 3 Provides most positive warning where crew must take action.	Warning devices for items that require immediate corrective action must be positive.



ASSUMPTIONS:

1. NORMAL TAKEOFF REQUIRES 12 SECONDS

Figure 8. High-Lift Devices Failure

Degraded Mode: HIGH LIFT DEVICES FAIL DURING TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.1.4 Taxi and Takeoff												
2.1.1.4D.5 High Lift Devices Fail After V_1		1. Detect failure.	1. Device position comparison with standard.					Ref. 2.1.1.4, Vol. II		Machine	Present warning with recommended action (see trade study "Warning Devices" attached to 2.1.1.4D.3)	Tactile/Voice and video warning and recommendation.
		2. Warn crew.	2. Visual, auditory and tactile	Master Caution, Intercom, HUD/ VSD, Tactile				" "		Machine		
		3. Monitor warning and procedures.	3. Message in storage	HUD/VSD MPD	Primary Flight Controller	Min. - 0 Max. - 10.0	2.0	" "	1.0	Man	Note: Cross tie between high lift devices normally prevents asymmetric operation.	
		4. Determine aircraft controllability.	4 Symmetrical or asymmetrical operation	HUD/VSD		" "	2.0	" "	1.0	Man		
	2.1.1.4D.5.1 Assess Situation	1. Consider: • R/W length required to abort • Usable R/W remaining • V_1 speed • A/C controllability • FMAC instructions				Min. - 0 Max. - 10.0 " " " " " " " "	1.0 1.0 1.0 1.0 1.0 1.0	" " " " " " " " " " " "	1.0 1.0 1.0 1.0 1.0 1.0	Man		
		2. Decision						" "				
	2.1.1.4D.5.2 Continue Takeoff	1. Actuate high lift retraction.	1. A/C controllable and high lift devices available		L.Console	TNC	1.5	" "	1.0	Man		
		2. Monitor lift device status.	2. Lift device positioning status	MPD	Primary Flight Controller Comm./Ident. Panel		2.0	" "	1.0	Man		
		3. Rotate aircraft.	3. Speed sufficient for liftoff	HUD/BSD/M—D		TNC	2.0	" "	1.0	Man		
		4. Communicate and inform.	4. Radios available	HUD/VSD/MPD		TNC	2.0	" "	1.0	Man		
	2.1.1.4D.5.3 Abort Takeoff	Ref. 2.1.1.4D.3.2 "Abort Takeoff" Ref. 2.3.5D.1.3 "Engage Arrestment System"										
	2.1.1.4D.5.4 Eject Capsule	Ref. 2.1.1.4D.1.4 "Eject Escape Capsule"										

Degraded Mode: HIGH LIFT DEVICES FAIL DURING TAKEOFF

FUNCTION NO. CONDITION (continued)	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
2.1.1.4D.6 High Lift Devices Fail Before V_1		1. Detect failure. 2. Warn crew. 3. Monitor warning. 4. Determine aircraft controllability.	Same as 2.1.1.4D.5			Min. - 0 Max. - 10.0 " "	 2.0 2.0	Ref. 2.1.1.4, Vol II " " " " " "	 1.0 1.0	Machine Machine Man Man		
	2.1.1.4D.6.1 Assess Situation	1. Consider: R/W length required to abort Usable R/W remaining Present speed A/C controllability 2. Decision	Same as 2.1.1.4D.5.1			" " " " " " " " " "	1.0 1.0 1.0 1.0 1.0	" " " " " " " " " "	1.0 1.0 1.0 1.0 1.0	Man Man Man Man Man		
	2.1.1.4D.6.3 Abort Takeoff	See 2.1.1.4D.3.2 "Abort Takeoff"										
Ref. 2.3.5.4 Taxi												

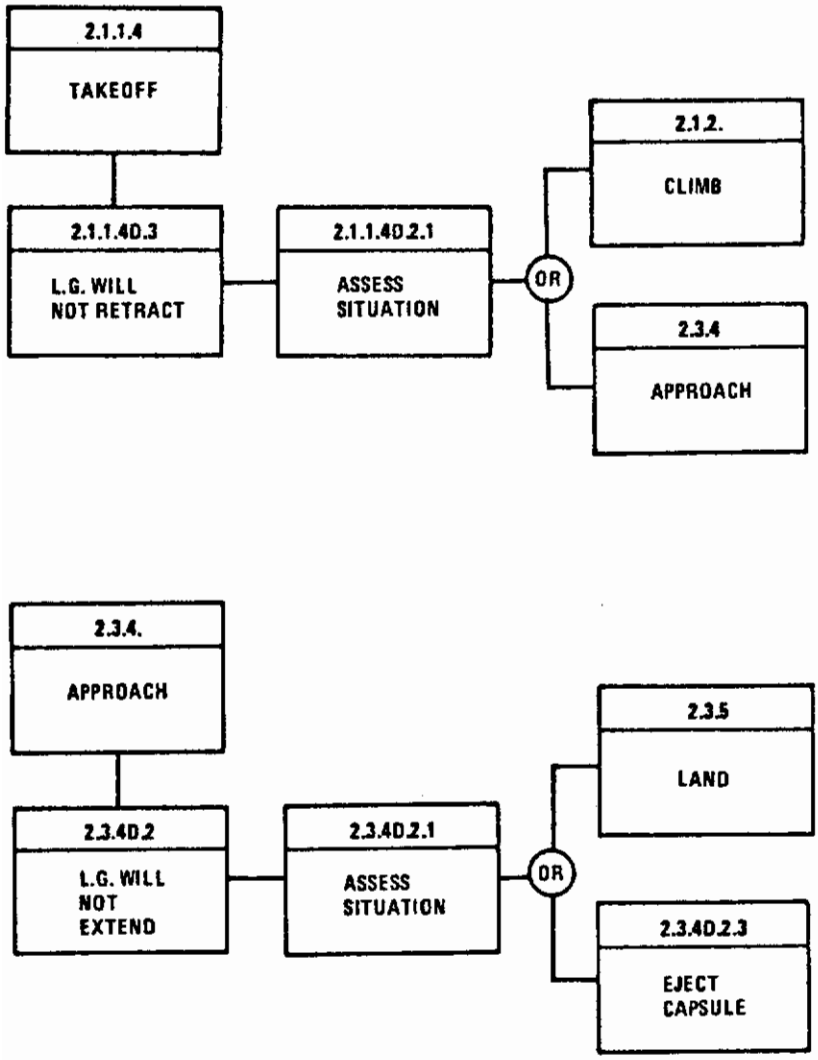


Figure 9. Landing Gear Failure

Degraded Mode: LANDING GEAR RETRACTION FAILURE - TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.1.4 Taxi & Takeoff												
2.1.1.4D.3 Landing Gear Will Not Retract		1. Actuate LG* control.	1. Control available		LG Control	TNC	1.5	Ref. 2.1.1.5 "Monitor & Control A/C"	1.0	Man Machine		
		2. Detect failure.	2. Compare with standard									
		3. Warn crew.	3. Visual, auditory	Master Caution, Voice, VSD/HUD		TNC	1.0	Ref. 2.1.1.6		Man/Machine		
		4. Monitor warning and procedures.	4. Preprogrammed instructions to crew	MPD	(Storage)	TNC	2.0	"Communicate"	1.0	Man		
		5. Communicate and inform.	5. Radios available (voice, D/L)	MPD	Comm./Ident. Panel & Mic.	TNC	5.0	" "		Man/Machine		
	2.1.1.4D.2.1 Assess Situation	1. Consider:										
		Type mission and fuel aboard						" "				
		Which gear is hanging						" "				
		FMAC procedures						" "				
		2. Decision				TNC	3.0	" "	1.0	Man		
	2.1.1.4D.2.2 Actuate Emergency Override	1. Actuate LG squat switch override.	1. Squat switch available		No	TNC	1.5	" "	1.0	Man	Require: Control to override LG squat switch.	See trade study- Mechanical Plunger Actuated by the Pilot.
		2. Observe LG position.	2. Gear position	MPD		TNC	2.0	" "	1.0	Man		
	Ref. 2.1.2 Climb	If LG retracts, continue mission, or if mission can be completed with gear hanging, continue mission.						" "				
	Ref 2.3.4 Approach	If LG remains down and mission cannot be completed, abort mission.						" "				

*LG - Landing Gear

Degraded Mode: LANDING GEAR RETRACTION FAILURE—TAKEOFF DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Squat switch override	OPTION NO. 1 Toggle switch	OPTION NO. 2 Pushbutton	OPTION NO. 3 Manual plunger	SELECTION	
CRITICALITY Low FREQUENCY OF USE Infrequent RESPONSE TIME Medium PRECISION REQUIREMENTS Momentary until gear retraction completed or gear selected down. ENVIRONMENT CONSTRAINTS LOCATION ALLOCATION VISION REACH Tertiary	Pro: 1. Discrete action required. 2. Can be located in tertiary area. Con: 1. Requires panel space. 2. Requires hood. 3. Requires illumination. 4. Dependent on source of power.	Pro: 1. Discrete action required. 2. Can be located in tertiary area. Con: 1. Requires panel space. 2. Requires hood. 3. Requires illumination. 4. Dependent on source of power.	Pro: 1. Discrete action required. 2. Can be located in tertiary area. 3. Independent of power source. Con: 1. Requires physical location of solenoid so plunger can be actuated with plunger. 2. Requires panel space. 3. Requires hood. 4. Requires illumination.	Option 3 Independent system.	

Degraded Mode: LANDING GEAR EXTENSION FAILURE - APPROACH AND LAND

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref.2.3.4 Approach 2.3.4D.2 Landing Gear Will Not Extend		1. Actuate normal LG* control. 2. Detect failure. 3. Garn crew. 4. Monitor warning and procedures. 5. Actuate emerg. LG control. 6. Monitor LG Position. position. 7. Use E-O sensors to observe LG. 8. Communicate and Inform.	1. Normal LG control available. 2. Disagreement of control and LG position. 3. Visual, auditory, tactile. 4. Preprogrammed instructions to crew. 5. Emergency control available. 6. Up-down-intermediate 7. Steer E-O** line-of-sight. 8. Radios available (voice).	Master Caution Voice, HUD/VSD MPD MPD VSD MPD	Normal LG Control (Storage) Emergency LG Control No Comm./Ident. Panel	TNC TNC TNC TNC TNC TNC	 1.5 10.0 10.0	Ref: 2.3.4.1 Volume II "Monitor & Control A/C." Ref. 2.3.4.2 "Navigate" Ref. 2.3.4.3 "Communicate" " " " "	12.0 12.0 12.0 12.0 12.0 12.0 12.0 12.0	Man Machine Machine Man Man Man Man/Machine Man/Machine	Require: Emergency landing landing control. Require: Means to individually slave E-O- line- of-sight.	See trade study attached "Hooded PB Switch" See analysis sheet "L^{3}TV/FLIR Fails" (2.2.3.8D.1) for trade study.
	2.3.4D.2.1 Assess Situation	1. Consider: • Which gear is hanging • Weapons aboard • WX environment • Fuel remaining • Base facilities Actual landing gear observation 2. Decision	Wheels up or eject capsule (see below)			TNC TNC TNC TNC TNC TNC	2.0 3.0 3.0 3.0 2.0	" " " " " " " " " " " " " "	6.0 6.0 6.0 6.0 6.0 6.0	Man Man Man Man/Machine Man Man		* LG - Landing Gear ** E-O - Electro-optical
	2.3.4D.2.2 Land Wheels Up	1. Notify tower of emergency and intentions. 2. Monitor base facilities preparations for wheels up landing.	2. Fire trucks, ambulance, runway foaming, etc.		Comm./Ident. Panel Comm./Ident. Panel	TNC Continuous	20.0	" " " "	Cont. Cont.	Man Man		
Ref. 2.3.5 Land	2.3.4D.2.3 Eject Capsule	See 2.1.1.4D.1.4, "Eject Escape Capsule" for sequence of events.							Cont.	Man		

Degraded Mode: LANDING GEAR EXTENSION FAILURE–APPROACH AND LAND DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Emergency L.G. control.	OPTION NO. 1 Discrete movement of landing gear control.	OPTION NO. 2 Covered pushbutton.	OPTION NO. 3 Covered toggle switch.	SELECTION	
				Option 2	
CRITICALITY High	Pro: 1. Same control used for normal operation. 2. Discrete twisting or overtravel motion. 3. Could be mechanical action.	Pro: 1. Same type switches as for normal operation. 2. Small panel space required. 3. Discrete action required.	Pro: 1. Small panel space required. 2. Discrete action required.	Conforms with type switches used on panel.	
FREQUENCY OF USE Infrequent	Con: 1. Requires lever installation on control panel. 2. Requires larger panel space.	Con: 1. Requires hood. 2. Dependent on electrical power.	Con: 1. Requires hood. 2. Dependent on electrical power.		
RESPONSE TIME Immediate					
PRECISION REQUIREMENTS Highly reliable					
ENVIRONMENT CONSTRAINTS					
LOCATION ALLOCATION					
VISION					
REACH Secondary					

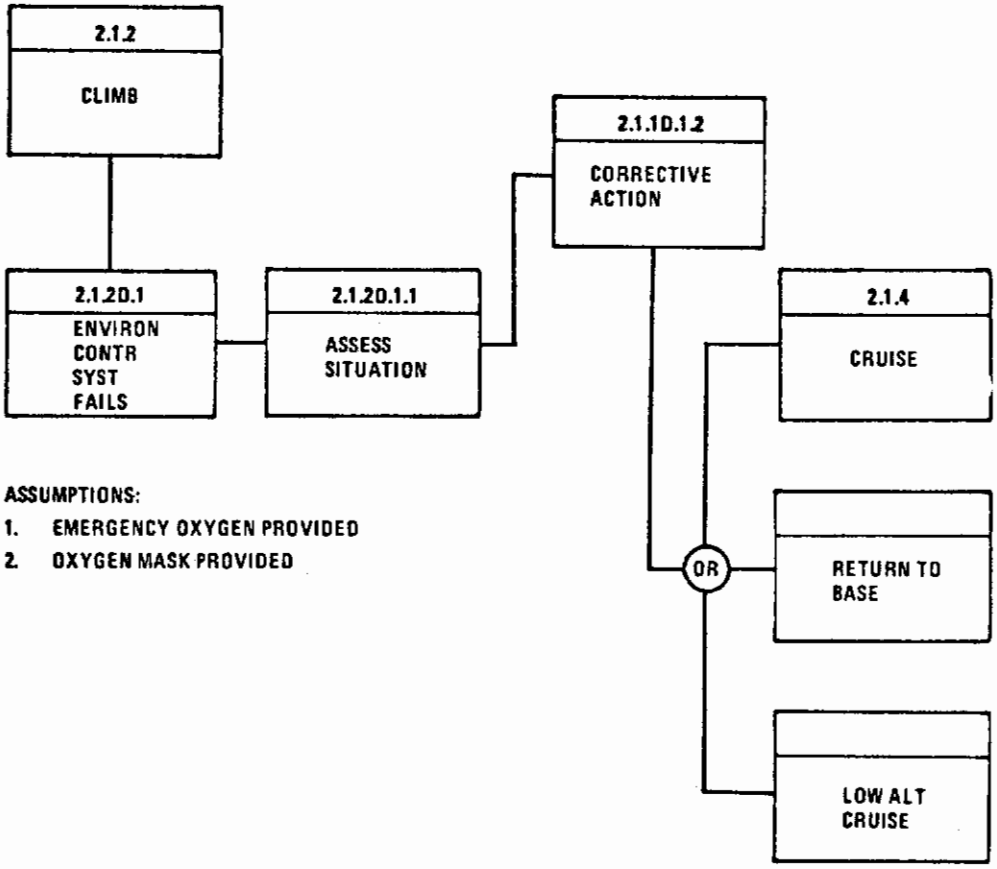


Figure 10. Environmental Control System Failure

Degraded Mode: ENVIRONMENTAL CONTROL SYSTEM FAILURE - CLIMB

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.2 Climb												
2.1.2D.1 Environmental Control System Fails		1. Sense malfunction.	1. Sense pressure, temp., contamination & compare with standard.	Master Caution, Voice, HUD/VSD				Ref. 2.1.2.1 "Monitor & Control A/C"		Machine		
		2. Warn crew.	2. Visual, auditory					Ref.2.1.2.2		Machine		
		3. Monitor warning and procedures.	3. Warning msg. in storage.	MPD	(Storage)	5.0	2.0	"Navigate"	3.0	Man	Require: Altitude hold,	See revised keyboard "Items"
		4. Alter climb schedule.	4. Autopilot disconnect & hold alt.	MPD	No	5.0	3.0	" "	3.0	Man/Machine	Airspeed hold.	● Airspeed hold
		5. Communicate and inform.	5. Radios available (voice, D/L)	MPD	Comm./Ident. Panel & Mic.	TNC	4.0	" "	3.0	Man/Machine		● Altitude hold
												● Enter
												(Aircraft levels off and holds altitude and airspeed.)
	2.1.2D.1.1 Assess Situation	1. Consider										
		Safety of flight						" "				
		Environment						" "				
		Mission criticality						" "				
		Oxygen supply						" "				
		FMAC instructions						" "				
		2. Decision					3.0	" "				
	2.1.2D.1.2 Corrective Action	1. Activate emergency oxygen.	1. Emerg. O_2 supply "On"		ECS Panel	2.0	1.5	" "	3.0	Man	See "Fire During Refuel" for requirements.	See revised ECS Panel
		2. Don mask.	2. Masks available		(Stowed)	(Depends on alt.)	3.0	" "	3.0	Man		Emerg. O_2
		3. Cycle ECS system.	3. ECS "On" - "Off"			TNC	3.0	" "	3.0	Man		● On
		4. Monitor system status.	4. N, master caution	MPD		TNC	2.0	" "	3.0	Man/Machine		(Revised Vol 1 - O_2 Panel) Oxygen blinker to indicate system operation- should be in primary vision area.
	2.1.2D.1.3 System Normal	1. Return to "Climb" schedule	1. Engage "Nav Steer" and "Alt. CMD"	HUD/VSD/MPD	AFCS Panel	TNC	3.0	" "	1.0	Man/Machine	Rapid means of selecting course to base.	See revised keyboard for: "Nav" ● Base ● Enter or "Nav" ● Modify ● Altitude ● LegXX ● Enter
	2.1.2D.1.4 System Abnormal	1. "Return to base" or	1. Select "Base" for new destination.	MPD	Keyboard	TNC	3.0	" "	2.0	Man/Machine	Means to modify flight plan.	
		2. "Continue mission at low altitude."	2. Modify preprogrammed mission for altitude change.	MPD	Keyboard	TNC	5.0					

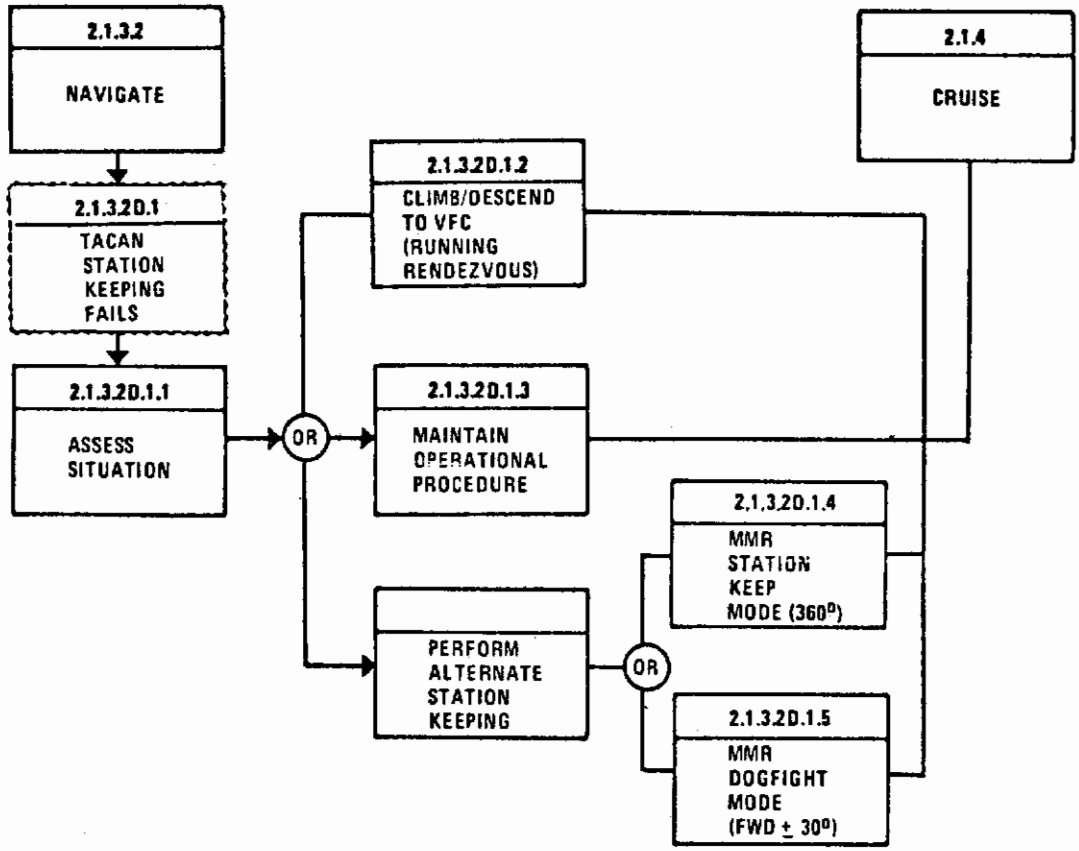


Figure 11. TACAN Station Keeping Function Fails During Rendezevous

Degraded Mode: TACAN STATION KEEPING FAILS - RENDEZVOUS

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref.2.1.3.2 Navigate												
2.1.3.2D.1 TACAN Station Keeping Fails		1. Detect failure.	1. Fault exists.	Master Caution Voice, HUD/VSD MPD						Machine		
		2. Warn crew.	2. Visual, auditory.			5.0	2.0	Ref.2.1.3	3.0	Man/Machine		
		3. Monitor FMAC instructions.	3. Preprogrammed msg. to crew.			5.0	3.0	"Rendezvous"	3.0	Man		
		4. Communicate with other aircraft and mission control.	4. Radio modes (voice, D/L).		Comm./Ident. Panel & Mic.	5.0	3.0	"	3.0	Man		
	2.1.3.2D.1.1 Assess Situation	1. Consider:										
		Fault				10.0	2.0	"		Man		
		Weather				10.0	1.0	"		Man		
		Position relative to other A/C in formation				10.0	2.0	"		Man		
		Alternate sensors				10.0	2.0	"		Man		
		FMAC/CCC instructions				10.0	(Included in (3) above)	"		Man		
						10.0	2.0	"		Man		
		2. Make decision.										
	2.1.3.2D.1.2 Climb/Descend to VFC (Running rendez-vous if lead A/C) or	1. Maintain present climb status.	1. Items + attitude	HUD/VSD				Ref. 2.1.3	3.0	Machine		
		2. Maintain speed.	2. Items	HUD/VSD				"Monitor & Control A/C	3.0	Machine		
		3. Maintain alt./climb rate.	3. Items	HUD/VSD				and Provide Identity"	3.0	Machine		
		4. Monitor ground position.	4. Map/charts	HSD/MM		TNC	2.0	"	3.0			
		5. Communicate with other A/C.	5. Radio modes avail. (voice)	MPD	Comm./Ident. Panel	TNC	(Included above)	"	3.0	Man	See revised Comm./Ident. Panel for transmit and receive.	
	2.1.3.2D.1.3 Maintain Operational Procedure (If flying wing position)	1. Alter heading.	1. Items	HUD/VSD		5.0	2.0	"Provide Identity"		Man		
		2. Maintain alt./climb rate.	2. Items	HUD/VSD				"		Man/Machine		
		3. Monitor attitude.	3. Items + attitude	HUD/VSD		TNC	3.0	"		Man/Machine		
		4. Monitor speed.	4. Items	HUD/VSD				"		Man/Machine		
		5. Monitor ground position.	5. Coordinates, map data	HSD/Map		TNC	2.0	"		Man		
		6. Communicate with other A/C.	6. Radio modes avail. (voice)	MPD	Comm./Ident. Panel		(Included above)	"		Man		

Degraded Mode: TACAN STATION KEEPING FAILS - RENDEZVOUS

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL./ WHERE	CONTROL AVAIL./ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
	2.1.3.2D.1.4 Perform MMR Station Keeping (360°)	1. Communicate	Freq./Ch.	MPD	Comm. Panel	10.0	3.0	Ref. 2.1.3		Man/Machine		
		2. Alter course	Gr. track, Δheading	HUD/VSD,HSD		10.0	2.0	"Provide Identity"		Man		
		3 Alter speed.				10.0	2.0	" "		Man		
		4. Alter climb rate.	Items + attitude	HUD/VSD		10.0	2.0	" "		Man		
		5. Monitor attitude.				10.0	1.0	" "		Man		
		6. Maintain relative spacing.	Range, bearing, altitude.	HUD/VSD,HSD		10.0				Man		
	2.1.3.2D.1.5 Activate MMR Dogfight Mode (±30°)	1. Maintain course.	Ground track	HUD/VSD,HSD		TNC		Ref. 2.1.3		Machine		
		2. Maintain speed.				TNC		"Provide Identity"		Machine		
		3. Maintain climb rate.	Items + attitude	HUD/VSD		TNC		" "		Machine		
		4. Monitor attitude.				30.0	2.0	" "		Man		
		5. Communicate with other A/C in formation.	Radio available (freq./ch.)		Comm./Ident. Panel	30.0	3.0	" "		Man		
		6. Alter speed and climb rate to maintain trail position.	Items	HUD/VSD		30.0	5.0	" "		Man		
		7. Select MMR "dogfight" mode.	MMR mode available		Radar Mode Select Panel	30.0	2.0	" "		Man		
		8. Monitor A/A lock-on.	A/A tracking symbology	HUD/VSD/HSD		30.0		" "		Man		Revise keyboard "FCS" Station Keep R Min. XX Ft. Pursuit Enter
		9. Set range to desired aircraft spacing (min.range).	Range increments (ft. or nm)		NO	30.0	6.0	" "		Man	"Range Separation" selection.	
		10. Select "pursuit" A/A mode.			NO	30.0	2.0	" "		Man	Select "Pursuit" for A/A following in trail.	
		11. Engage WCS steering.	AFCS steering mode available.		AFCS Mode Select Panel	30.0	2.0	" "		Man		
		12. Engage auto speed control.	AFCS speed control available.		Thrust Cmd. Control	30.0	1.0	" "		Man		
		13. Monitor relative position in trail.	Range, bearing	HUD/VSD/HSD		30.0		" "		Man		
Ref. 2.1.4 Cruise												

Degraded Mode: TACAN STATION-KEEPING MODE FAILS DURING CLIMB AND RENDEZVOUS

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Select range separation during climb and rendezvous (auxiliary station keeping).	OPTION NO. 1 Rotary switch with variable range selection.	OPTION NO. 2 Keyboard control.	OPTION NO. 3 Voice operated.	SELECTION	
CRITICALITY High **FREQUENCY OF USE** Low **RESPONSE TIME** Medium **PRECISION REQUIREMENTS** Not critical **ENVIRONMENT CONSTRAINTS** **LOCATION ALLOCATION** **VISION** Secondary **REACH** Secondary	Pro: 1. Simple, positive. 2. Can be turned in either direction. 3. Good visual association. Con: 1. Must provide space for control seldom used. 2. Not multipurpose.	Pro: 1. Can use set of keys for multitude of selections. 2. Very little additional space required over those already used for other system inputs. 3. Good accuracy. 4. Compatible with digital equipment. 5. Versatility of common inputs. Con: 1. Must see to operate some functions (for example, select options). 2. Takes too long for one or two inputs compared to other type control devices.	Pro: 1. Very little physical movement involved. 2. Leaves hands free to do other tasks. 3. No panel space used. 4. Will accept all spoken words. Con: 1. May not reduce pilot workload if voice communications are also required with other aircraft. 2. Complex.	Option 2 Compatible with other keyboard tasks performed. Select "FCS" and "Station Keep- R. Min." Desired range is then selected. Note: Additional selection of "Pursuit" is added as a keyboard option whenever "station keeping" appears.	

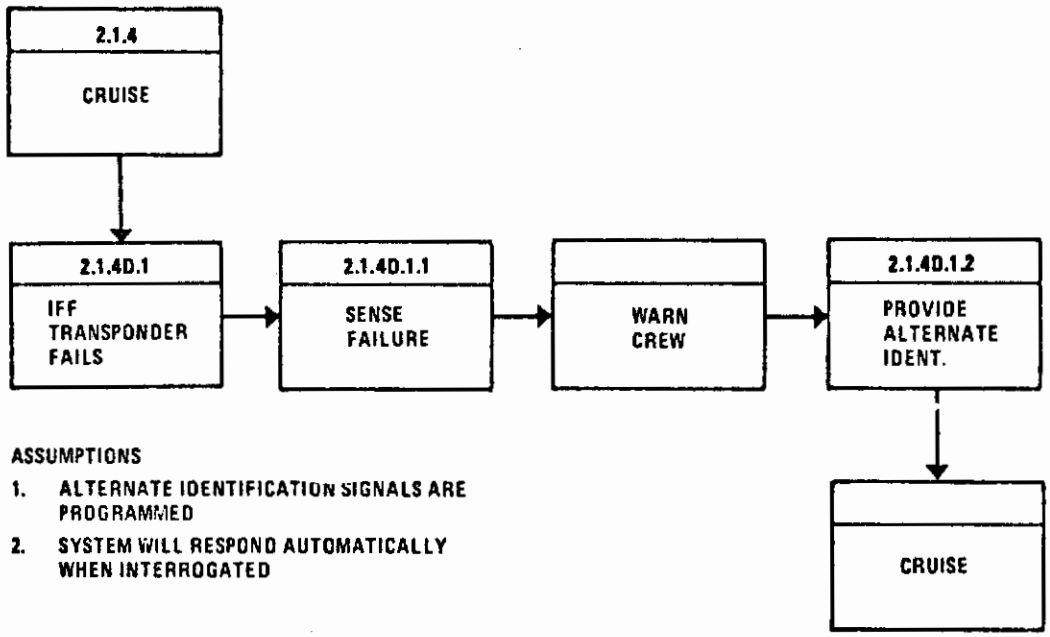


Figure 12. IFF Transponder Failure

Degraded Mode: IFF TRANSPONDER FAILURE - CRUISE

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref.2.1.4 Cruise												
2.1.4D.1 IFF Transponder Fails (A/A & A/G)		1. Detect failure. 2. Warn Crew. 3. Monitor FMAC instructions. 4. Communicate with BAC.	1. Fault exists. 2. Visual, voice. 3. Preprogrammed instructions. 4. Radio modes available (voice, data link).	Master Caution, VSD/MPD, Voice MPD MPD	(Storage) Comm./Ident. & Throttle Mic.	TNC TNC TNC	2.0 3.0 5.0	Ref.2.1.2 "Monitor & Control A/C.." "Navigate" " "	3.0 3.0 3.0	Man Man/machine Man Man/Machine		
	2.1.4D.1.1 Assess Situation	1. Consider: Fault Alternate Systems Environment Position relative to CONUS Friendly Aircraft in Immediate Area FMAC Instructions 2. Decision				TNC TNC TNC TNC TNC TNC TNC	1.0 1.0 1.0 1.0 1.0 (Included in (3) above) 2.0	(Same as 2.1.2 above) " " " " " " " " " " " "	3.0 3.0 3.0 3.0 3.0 3.0 3.0	Man Man Man Man Man Man Man		
	2.1.4D.1.2 Provitr Procide Alternate Identification	1st Alternate 1. Check guard rec. on. 2. Respond with proper signal when interrogated on secure directional circuit.	1. Secure comm."Guard" on. 2. Secure voice/DL "Code of the Dev" response.	Comm./Ident. Comm./Ident.	Control Panel Control Panel	TNC TNC	1.5 3.0	" " " "	2.0 2.0	Man Man/Machine	A new concept for positive identification of aircraft is required. (See discussion-next sheet.)	
		2nd Alternate 1. Notify wingmen to turn on his IFF.	Note: Backup when escorted by wingman;		Comm./Ident. Panel & Throttle Microphone	TNC	3.0	" "	1.0	Man		
		3rd Alternate 1. Turn on MMR to provide signal for RHAW analysis.	Note: This is to emit signals for analysis.		Radar Mode Select Panel	TNC	1.5	" "		Man		

Degraded Mode: IFF TRANSPONDER FAILS

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref.2.2 Combat	(continued)	4th Alternate 1. Make recognition turns on time as required by interrogating station.	1. Communication with interrogating station established. Turn directions on time.		Items	TNC	Varies	Ref.2.1.2		Man/Machine		

DISCUSSION:

Secure/Directional Identification

The positive identification equipment installed in this aircraft as an alternate to IFF employs the secure/directional spread spectrum radio equipment to interrogate unidentified aircraft and to respond when interrogated. Interrogation functions are discussed under "IFF INTERROGATOR FAILS-A/A" analysis sheet.

When interrogated on secure/directional communication frequency (guard frequency) the system senses incoming signals with a discrete identification address. A returned programmed response is provided in the reciprocal direction. Requirements are as follows:

1. Secure/directional antennas provide 360° coverage for receiving/transmitting.
2. INTERROGATOR sends continuous signal during interrogation to provide receiver lock-on capability.
3. Computer is preprogrammed to turn on guard transmitter and send required response when interrogated.
4. Voice identification is also permitted for proper response when interrogated.

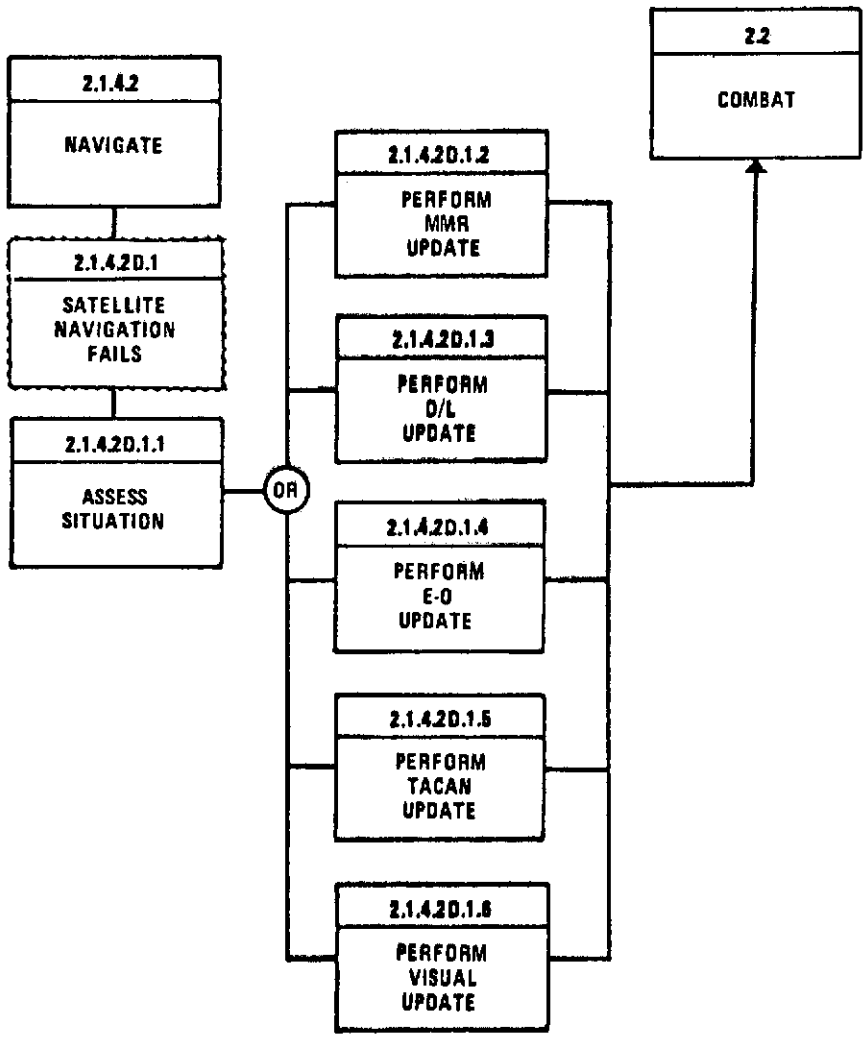


Figure 13. Satellite Navigation Fails

Degraded Mode: NAVIGATION SATELLITE TRACKING FAILS - CRUISE

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.1.4.2. Navigate 2.1.4.2D.1. Navigation Satellite Tracking Fails		1. Detect failure 2. Warn crew. 3. Monitor warning and instructions. 4. Communicate and inform BAC	1. Fault exists 2. Visual, auditory 3. Preprogrammed msg. 4. Radio modes available (secure, clear, voice, D/L)	Master Caution Voice, HUD/VSD MPD MPD	 Comm./Ident. Panel	TNC TNC TNC	1.0 3.0 5.0	Ref. 2.1.4 "Monitor & Control A/C" "Identify" " "	3.0 3.0 3.0	Machine Man/Machine Man Man/Machine	Add: FMAC warning and volume control to Comm./Ident. Panel.	
	2.1.4.2D.1.1 Assess Situation	1. Consider: o System failed o High/low altitude accuracy reqmts. o Weapon del. requirements o FMAC/CCC instructions 2. Decision				TNC TNC TNC TNC TNC	2.0 2.0 2.0 (Included in (3) above) 2.0	" " " " " " " " " "	4.5 4.5 4.5 4.5 4.5			
	2.1.4.2D.1.2 Perform MMR Update	1. Select NAV update 2. Select ground reference point. 3. Compute range to CP(1) 4. Inform crew when update is available. 5. Perform crosshair lay on predicted CP. 6. Select hi res. radar GM mode and display area about crosshair. 7. Locate CP on display. 8. Correct crosshair to CP. 9. Activate computer update.	1. MMR update 2. Precision/NAV CP XX 3. CP and PP(2) lat. long. 4. Within range status 5. CP/crosshair symbol 6. Spotlight mode, display area (1x1 or 2x2 nm) 7. Map and briefing data with MMR video at flicker rate. 8. Cursor/target relative position error 9. Update	No MPD Keyboard MPD No Aux. Radar/ Map Control Keyboard HSD/MM HSD/MM	 	TNC	3.0 1.0 1.5 3.0 3.0 2.0 1.5	" " " " " " " " " " " " " " " " " " " "	4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5	Man Man/Machine Machine Man/Machine Man Man Man/Machine Man	Require means for radar update. Recommend addition of "manual X-Hair lay so that pilot may perform X-Hair lat at his discretion. Require means to flicker radar/map. Require means to control crosshair. Require means to "freeze" display.	Keyboard Control "NAV" mode Crosshair Lay Enter Keyboard Control C&D - HSD Flicker (selected rate) Use Designation Control as primary with voice as backup. Designation Control Freeze Erase

Note: If, during low altitude navigation, longer look is required in order to identify the CP, activate a "Freeze" display method. A synthetic crosshair, in addition to frozen crosshair, is generated and controlled by the designation control in same manner as real crosshair is controlled when display is not frozen.

(1) CP – Check Point
(2) PP – Present Position

Degraded Mode: NAVIGATION SATELLITE TRACKING FAILS – CRUISE

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Cont	2.1.4.2D.1.3 Perform D/L Update	1. Communicate 2. Monitor D/L instructions. 3. Select sensor input to compute. 4. Select NAV update method. 5. Activate computer load. 6. Activate update. 7. Monitor loading status. 8. Monitor update status.	1. Radio modes (sec,voice, D/L) 2. N 3. D/L input available 4. D/L update 5. Load 6. Update available 7. Loading complete 8. Update complete	MPD Mission Control Panel MPD	Comm./Ident Panel Mission Control Keyboard Control Mission Control Panel DesignationControl/Voice	TNC TNC TNC TNC TNC TNC TNC TNC	5.0 2.0 1.5 1.5 1.5 1.5 5.0 2.0	Ref. 2.1.4 "Monitor & Control A/C" "Identify" " " " " " " " " " "	6.0 6.0 6.0 6.0 6.0 6.0 6.0 6.0	Man/Machine Man Man Man Man Man Man/Machine Man/Machine	Require: Means to select D/L input to CCC. Means to select D/L update. Means to activate CCC "load." Require backup "update" control	See revised Mission Control Panel. See revised Keyboard. See revised Mission Control Panel. "Voice" input to CCC. See throttle controller for comm./voice micro phone control.
	2.1.4.2D.1.4 Perform E–O Update	1. Select NAV update. 2. Select ground ref. point. 3. Monitor CP briefing data. 4. Alert pilot when selected ref. pt. is within range. 5. Perform crosshair lay on CP. 6. Verify crosshair position. 7. Activate E–O sensor. 8. Select field of view. 9. Identify checkpoint in TV/FLIR field of view. 10. Refine crosshair on aimpoint. 11. Activate laser ranging. 12. Activate computer update.	1. E–O update 2. Precision/NAV CP XX 3. Coordinates, aimpoint, terrain data 4. CP "in range" 5. Auto crosshair lay 6. Mapping data 7. L^3 TV/FLIR "On" 8. Wide/narrow FOV 9. Target/background contrast level adequate 10. Cursor/target relative position error 11. Laser ranging "On" 12. Update	MPD HSD/Map MPD MPD HSD/MM HUD/VSD HUD/VSD	Keyboard Keyboard Sensor/Display Select Panel E-O Aux. Sensor Control No Radar Mode Select Panel Designation Control/ Voice	20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0 20.0	1.5 1.5 3.0 1.0 2.0 1.5 1.5 2.0 3.0 1.5 1.5	Same as "Ref. 2.1.4" above "	7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0	Man Man Man Man/Machine Machine Man Man Man Man/Machine Man Man	Means to select E–O NAV update. Means to auto or manually lay crosshair. Means to select steerable L^3 TV or FLIR. Means to drive crosshair Means to NAV update.	See revised Keyboard Panel. See revised Keyboard NAV–"Crosshair Lay." See modified Sensor/ Display Select Panel for Steer "On-Off." Designation control as primary with voice as secondary. See revised designation control–update switch added.
Ref. 2.2 Combat	2.1.4.2D.1.5 Perform TACAN Update	1. Select TACAN NAV update. 2. Select TACAN station. 3. Identify station 4. Monitor in range. 5. Verify location. 6. Activate update.	1. TACAN available 2. Ch. available 3. Audio 4. Range to station 5. Range and bearing to station 6. NAV update	MPD MPD HSD/Map	Keyboard Keyboard Comm./Ident Panel	TNC TNC TNC TNC TNC TNC	1.5 5.0 3.0 1.0 2.0 1.5	Ref. 2.1.4 "Monitor & Control A/C" "Identify" " " " " " "	5.0 5.0 5.0 5.0 5.0 5.0	Man Man Man Man Man Man	Require: Means to update with TACAN. Require: Means to perform update.	See Keyboard Control "NAV" TACAN update. Designation Control o NAV Update or voice on throttle control o Mic o Computer
	2.1.4.2D.1.6 Perform Visual Update	1. Select update method. 2. Set in ground ref. coordinates. 3. Select update when over ground ref. point.	1. Visual update available 2. CP XX 3. NAV update		Keyboard Keyboard Designation Control/Voice	TNC TNC TNC	3.0 3.0 0.5	Ref. 2.1.4 "Monitor & Control A/C" " "	2.0 2.0 2.0	Man Man Man	Require: Means to update visually. Require: Means to perform update.	Add to Keyboard Cont "NAV" – visual update. Designation Control "Update" is primary with voice as secondary (on throttle control).

Note: Freeze/erase capability exists for any TV/FLIR presentation–see 2.1.4.2D.2 "Perform MMR Update."

Degraded Mode: NAVIGATION SATELLITE TRACKING FAILS - CRUISE

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Command X-Hair to drive in range, azimuth and elevation	OPTION NO. 1 Voice augmented X-Hair control.	OPTION NO. 2 Designation control.	OPTION NO. 3 Light pen method for target designation	SELECTION	
CRITICALITY High FREQUENCY OF USE High RESPONSE TIME High PRECISION REQUIREMENTS High ENVIRONMENT CONSTRAINTS LOCATION ALLOCATION VISION Primary REACH Primary	Pro: 1. Leaves hands free to do other tasks. 2. Little physical movement required. 3. No panel or control space use. Con: 1. Need to insert voice signature cards into the computer. 2. Interferes with other communications	Pro: 1. Many functions could be handled on a single stick control. 2. Good space factor considering all jobs it must perform. 3. May be stowed out of the way when not used. Con: 1. Takes space when used. 2. Requires a hand to operate which may require other functions to wait.	Pro: 1. Direct interface with man and display 2. Can perform with glove. Con: 1. Prime vision area is not same as prime reach area. 2. Difficult to designate a target in turbulence or high "G." 3. Pen must be stowed near display or carried on person.	Option No. 2 Designation control is primary with voice as backup.	

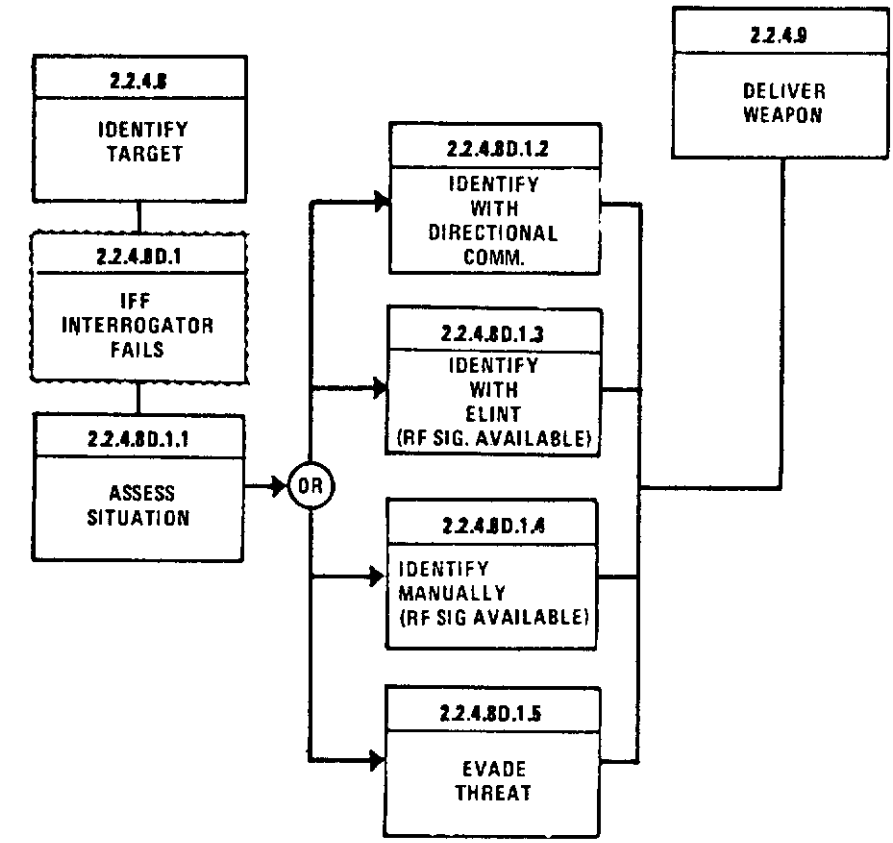


Figure 14. IFF Interrogator Fails During Air-To-Air Combat

Degraded Mode: IFF INTERROGATOR FAILS – AIR-TO-AIR COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.4.8 Identify Target		1. Analyze signature. 2. Alert pilot that target is unidentified. 3. Interrogate bogey.	1. IR/RF emissions 2. N and discrete information 3. MMR track & A/A IFF avail.	MPD/HSD	No			Ref. 2.2.4.1 "Monitor & Control A/C," "Navigate" & "Provide Identity"		Machine Man/Machine Men/Machine	Provide means to manually interrogate bogey with MMR	See revised Comm./ Ident. Panel. Illuminated push button – MMR • "IFF Interrogate On/Off" • IFF Response
2.2.4.8D.1 IFF Interrogator Fails		1. Detect failure. 2. Warn crew. 3. Monitor warning and instructions. 4. Shut down system. 5. Communicate and inform.	1. Fault exists 2. Visual, auditory & tactile 3. Preprogrammed msg. to crew 4. Preprogrammed CCC instruct. 5. Radio available (voice & D/L)	Master Caution, Voice, HUD/VSD MPD MPD	(Storage) Comm./Ident. Panel & Mic.		1.0 3.0 5.0	" " " " " "	2.0 2.0 2.0 2.0	Machine Man Man Machine Man/Machine		
	2.2.4.8D.1.1 Assess Situation	1. Consider Fault Type threats in area Friendly A/C in area Environment Alt. means of identification Instructions from FMAC & BAC* 2. Make decision.				15.0 15.0 15.0 15.0 15.0 15.0 15.0	2.0 2.0 2.0 2.0 2.0 (Included in (3) above) 2.0	" " " " " " " " " " " " " "	3.0 3.0 3.0 3.0 3.0 3.0 3.0			
	2.2.4.8D.1.2 Identify Threat with Directional Comm.	1. Monitor presence of bogey. 2. Designate bogey. 3. Select secure comm. ident. on guard channel. 4. Interrogate. 5. Monitor interrogation response. 6. Identify as friend or foe.	1. (See signature analysis above) 2. MMR skin paint & X-heirs 3. Spread spectrum secure ident. available 4. Directional comm, ident. avail. 5. Audio/video reply 6. N plus symbology	MPD/HSD MPD/HSD MPD/HSD MPD/HSD	Designation Control No No	20.0 20.0 20.0 20.0 20.0 20.0	3.0 3.0 1.5 1.5 1.0 1.0	" " " " " " " " " " " "	3.0 3.0 3.0 3.0 3.0 3.0	Man Man Man Man Man Man	Require alternate means to interrogate aircraft (other than radar). Require means to monitor IRR response.	See revised Comm./ Panel. IFF • Directional Communications See revised Comm./ Ident. Panel. IFF • Response

*BAC – Battle Area Commander

Degraded Mode: IFF INTERROGATOR FAILS – AIR-TO-AIR COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
(cont)	2.2.4.8D.1.3 Identify with ELINT* (RF Signal Available)	1. Cross-correlate RF/IR received data with stored characteristics. 2. Catalog & display threats (known and unknown). 3. Prioritize if known. Maintain surveillance if unknown. 4. Request identity. 5. Monitor threat identity and status.	1. Freq., PW, PRF, SR, polarization, and IR spectrum 2. Air-to-air and air-to-ground threats position and status 3. Highest to lowest priority of known; position only of unknown 4. Results of analysis 5. Threats or unknowns position and status	BSD MPD, HSD BSD, HSD		TNC	3.0	Ref. 2.2.4.1 "Monitor & Control A/C," "Navigate" and "Provide Identity"	1.0 1.0 1.0 1.0 1.0	Machine Machine Machine Machine Man	Provide means to identify threats with pen aids. Require appropriate symbology for threat priority position & status in addition to pen aids instructions.	Use Keyboard Control ATA A/A threats Battle Situation Display Threat •Known/Unknown •Position •Priority •Status
	2.2.4.8D.1.4 Identify Unknown Threats through D/L	1. Monitor unknown threats. 2. Designate threat. 3. Monitor threat characteristics. 4. D/L to battle area command post if unable to identify. 5. Receive threat identity and negation procedures.	1. Position (range, elev. and bearing) 2. X-hairs 3. Freq., PW, PRF, SR and polarization with audio 4. Secure comm. D/L available 5. Secure comm. D/L and/or voice instructions	BSD, HSD HSD/BSD MPD MPD	Designation Control Commitment Panel Keyboard & Comm./Ident. Panel Comm./Ident. Panel	20.0 20.0 20.0 20.0 20.0	2.0 2.0 3.0 5.0 5.0	" " " " " " " " " "	5.0 5.0 5.0 5.0 5.0	Man Man Man Man/Machine Man/Machine	Provide means to request command & control to assist in identity.	Pen Aids Instructions •Evade •Degrade •Destroy Comm./Ident. Panel Position XX Mode D/L Keyboard Control Pen Aids •Designated Identity requested
Ref. 2.2.4.9 Deliver Weapon	2.2.4.8D.1.5 Evade Threat	1. Alter course and speed to increase bogey angular rate and range. 2. Communicate with command and control.	1. Steering cmd.'s for course, altitude and speed. 2. Secure voice comm. position and mode available	BSD/VSD	AFCS Panel Control Stick Comm./Ident. Panel	20.0 20.0	5.0 5.0	Ref. 2.2.4.1 "Monitor Enemy Activity" "Provide Identity"	3.0 3.0	Man Man	Require control stick steering (CSS).	See revised AFCS Panel •Autopilot On/Off Note: CSS provided at any time autopilot is "On."

Degraded Mode: IFF INTERROGATOR FAILS - A/A COMBAT

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Activate or inhibit IFF interrogate.	OPTION NO. 1 Lighted push button.	OPTION NO. 2 Keyboard control	OPTION NO. 3 Two-position toggle switch.	OPTION NO. 4 Voice control	SELECTION
CRITICALITY High FREQUENCY OF USE Medium RESPONSE TIME PRECISION REQUIREMENTS Low ENVIRONMENT CONSTRAINTS None LOCATION ALLOCATION VISION Primary REACH Primary	Pro: 1. Good space factor. 2. Good indication of status. 3. Suitable for data link and digital equipment. 4. Position can be visually verified, especially at night. Con: 1. Must be looked at to operate. 2. Lamps may fail.	Pro: 1. Good space factor. 2. Compatible with digital equipment. 3. Hand can stay in common area while performing other tasks. Con: 1. Takes too long for a single operation. 2. Must look at an MPD for interrogate status.	Pro: 1. Simple motion 2. Good space factor. 3. Does not require visual coordination for operation. Con: 1. Cannot use with DL. 2. Separate lighting.	Pro: 1. Leaves hands free to do other tasks. 2. No panel space used. Con: 1. Still takes a switch action to activate voice control. 2. May interfere with other aircraft communications. 3. Complex.	Option No. 1 Lighted Push Button on Comm./Ident. Panel A lighted push button requires little space, easily actuated, and shows interrogation status at all times, even when used with data link control. May be computer or manually controlled. A/A IFF Interrogate Radar Directional Communications

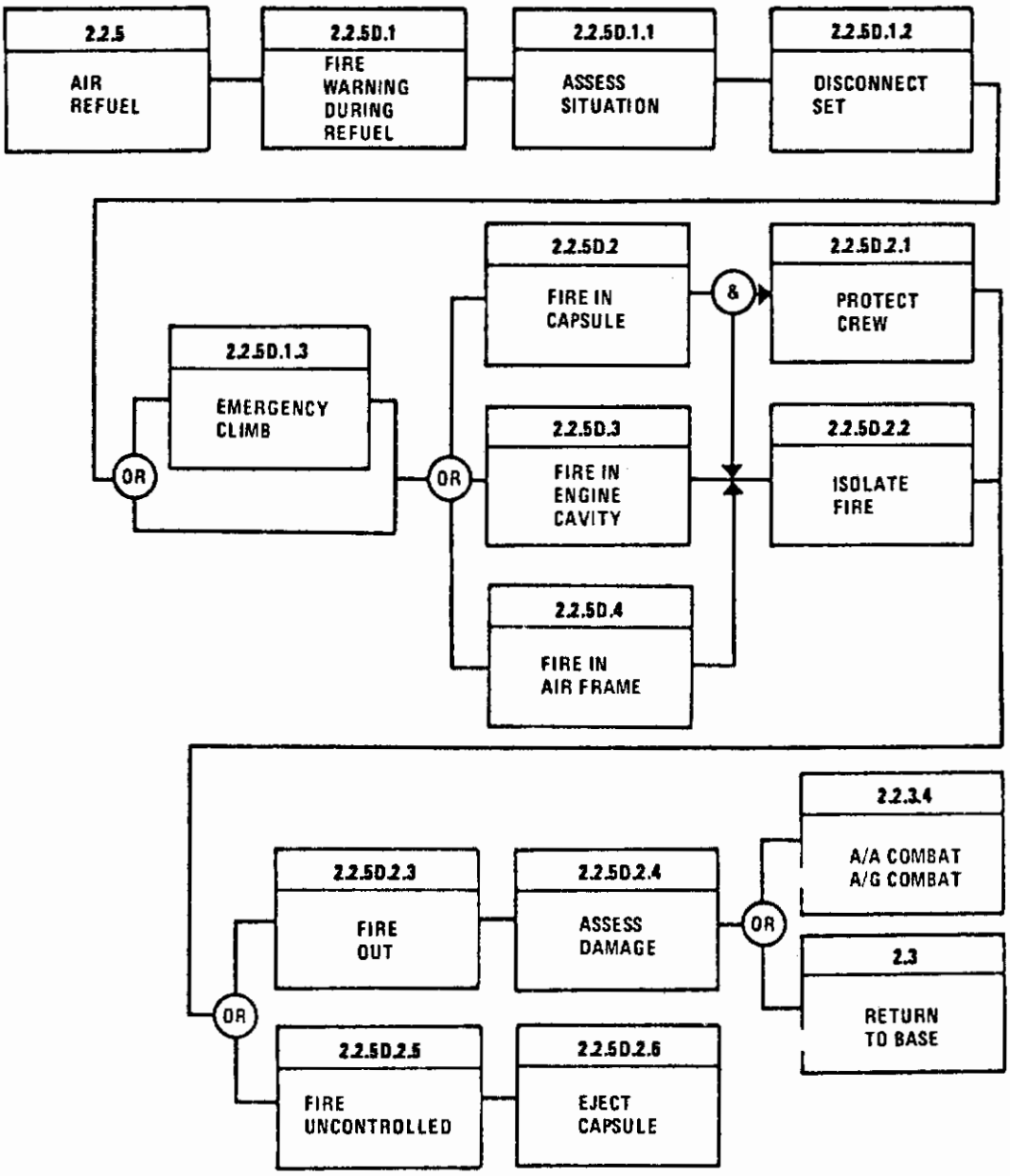


Figure 15. Fire During Refuel

Degraded Mode: FIRE - REFUEL

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.5 Refuel												
2.2.5D.1 Fire Warning During Refuel		1. Detect fire or overheat. 2. Warn crew. 3. Monitor warning and procedures. 4. Communicate with tanker.	1. Fire or overheat exists 2. Visual, auditory and tactile 3. Preprogrammed instructions 4. Radio available (boom intercom. voice)	Master Caution, Voice, HUD/VSD MPD MPD	 (Storage) Comm./Ident Panel, Mic.	 2.0 2.0 1.0	 1.0 2.0 1.0	Ref. 2.2.5 "Air Refuel" Vol.II Ref. 2.2.5.1 "Monitor & Control A/C" Ref. 2.2.5.2 "Navigate" Ref. 2.2.5.4 "Provide Identity"	 None None	Machine Men/Machine Man Man/Machine		
	2.2.5D.1.1 Assess Situation	1. Consider - Emergency procedures SOP requires disconnect so as not to endanger other aircraft. 2. Decision - Disconnect.				1.0	1.0	" "	None	Man		
	2.2.5D.1.2 Disconnect I.F.R.	1. Actuate high drag devices. Note: Use of speed brakes when in refuel mode will disconnect boom/drogue. 2. Decision - Climb or not.	1. Boom/drogue release at extension limits		No	2.0 5.0	1.5 2.0	" " " "	None	Men/Machine Man	Require: In-flight refuel break-away control.	See trade study(attchd) Speed brake control
	2.2.5D.1.3 Emergency Climb	1. Initiate climb to altitude to suppress fire. 2. Select maximum power. 3. Select optimum attack. 4. Retract high drag devices.	1. Minimum time-to-climb profile 2. Throttle control available 3. Items -Optimum attack 4. Speed brakes/spoilers	HUD/VSD MPD MPD	No Throttle Control Throttle Control	Varies with altitude TNC TNC 2.0	 1.5 2.0 1.5	" " " " " " " "	None None None None	Man/Machine Man/Machine Man Man/Machine	Requires Means to emergency climb.	"Items" Modify keyboard A/A intercept Enter Following actions will occur: 1. Max thrust 2. Optimum of attack 3. Steering signals 4. Retract speed brakes 5. Close refuel door
2.2.5D.2 Fire in Capsule	2.2.5D.2.1 Protect Crew	1. Activate emergency O_2. 2. Don mask. 3. Dump pressurization.	1. Flames/smoke in cockpit 2. Mask available 3. Dump and < 50 K altitude		ECS Panel (Stowed) ECS Panel	1 - 5.0 3.0 2.0	1.5 3.0 1.5	" " " " " "	None None None	Man Man Man/Machine	O_2 information required. Blinker in primary vision area. Quantity Pressure Flow data	
	2.2.5D.2.2 Isolate and Fight Fire	1. Turn off effected system 2. Activate fire suppressant system. 3. Observe results.	1. Avionics bus "non-essential off" 2. CO_2 bottles 3. Fire/smoke subsides	CAPSULE	Elect. Power Control Panel (Stowed)	4.0 TNC TNC	1.5 3.0 3.0	" " " " " "	None None None	Man Man Man		

Degraded Mode: FIRE – REFUEL

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
(continued)	2.2.5D.3 Fire in Engine Cavity	"Isolate and Fight Fire" See 2.2.5D.2.2. above										
	2.2.5D.4 Fire in Air Frame	"Isolate and Fight Fire" See 2.2.5D.2.2. above										
	2.2.5D.2.3 Fire Out	1. Sense fire/overheat 2. Present data 3. Decision - Fire out	1. 2. 3. } Fire or overheat no longer exists	Fire Warning VSD/HUD/MPD		TNC	5.0	Ref. 2.2.5.2 "Navigate" Ref. 2.2.5.1 "Monitor & Control A/C"	2.0	Man/Machine		
	2.2.5D.2.4 Assess Damage	1. Reactivate systems	1. Avionics power "On" of essential avionics		Elect. Power Control Panel Keyboard	TNC	1.5	Ref. 2.2.5 "Air Refuel"	10.0	Man/Machine		
		2. Activate FMAC systems test	2. FMAC capable of end-to-end check of systems			TNC	4.0	"	10.0	Man/Machine	Require: Improved means of testing systems to LRU level – requested by pilot	See revised FMAC keyboard controls. "FMAC" O FMAC status summary O Subsystem Name O Enter
		3. Present data	3. Subsystem status	MPD		TNC	20.0	"	10.0	Man/Machine		
		4. Provide alternate source for affected systme(s)	4. Alternate sources presented	MPD				"	10.0	Machine		
		5. Decision - Continue mission or return to base.	5. Based on above results			5.0	2.0	"	10.0	Man		
	2.2.5D.2.5 Fire Uncontrolled	1. Sense fire/overheat	1. External/internal			Continuous		Ref. 2.2.5 "Air Refuel"	None	Men/Machine		
		2. Present data,	2. Fire/overhead warning(s) persists	Fire Warning, Voice, VSD/HUD/MPD, Tactile					None	Machine		
		3. Observe data	3. Visual fire smoke/still exists wingmen communicates fire engulfing A/C or A/C is uncontrollable.	Visual		Continuous		"	None	Man		
		4. Decision - Fire uncontrolled	4. Based on facts above			2.0	1.0	"	None	Man		
		5. Decision - Eject	5. See "Eject Capsul."			2.0	1.0	"	None	Man		
	2.2.5D.2.6 Eject Capsule	Reference: Analysis Sheet 2.1.1.4D.1.4 "Eject Escape Capsule"										
Ref. 2.2.3/4 Attack/Combat Ref. 2.3 Return to Base												

Degraded Mode: FIRE - REFUEL

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS INFLIGHT REFUEL BREAK-AWAY CONTROL	OPTION NO. 1 SPEED BRAKE CONTROL ACTIVATES SYSTEM WHEN INFLIGHT REFUEL SELECTED AND HOOKED UP TO TANKER	OPTION NO. 2 AUTOMATIC - ACTUATES WHEN FIRE/OVERHEAD	OPTION NO. 3	SELECTION	
CRITICALITY FREQUENCY OF USE Infrequent RESPONSE TIME Rapid PRECISION REQUIREMENTS ENVIRONMENT CONSTRAINTS LOCATION ALLOCATION VISION REACH Primary	Pro: 1. Conveniently located. 2. Simple. 3. Permits option of "Go"/"No Go." 4. Reacts well in contingencies. 5. Tactile cue eliminates display Con: 1. Requires crew decision. 2. May be time critical. 3. Requires discrete action. 4. Must be reset.	Pro: 1. Fast reaction 2. No decision making delay. 3. Can sense small changes in stimuli. Con: 1. Requires display. 2. Complex 3. Can execute only as programmed 4. Sensitive to false signals.		Option No. 1 1. Provides positive control. 2. Simple. 3. Discretionary.	Note: When hooked up with the tanker and the inflight refuel switch is "on," if a fire warning is received operation of the speed brake control will cause the following: 1. FMAC to identify malfunction and send signal to CCC. 2. CCC will shut down identified circuit. 3. Disperse fire suppressant. 4. Sequence air refuel doors closed after break-away. 5. If smoke is present in cockpit, evacuate smoke. 6. Provide minimum time to climb program on MPD. 7. Provide instructions for activation of program on MPD. 8. Provide voice and video warning.

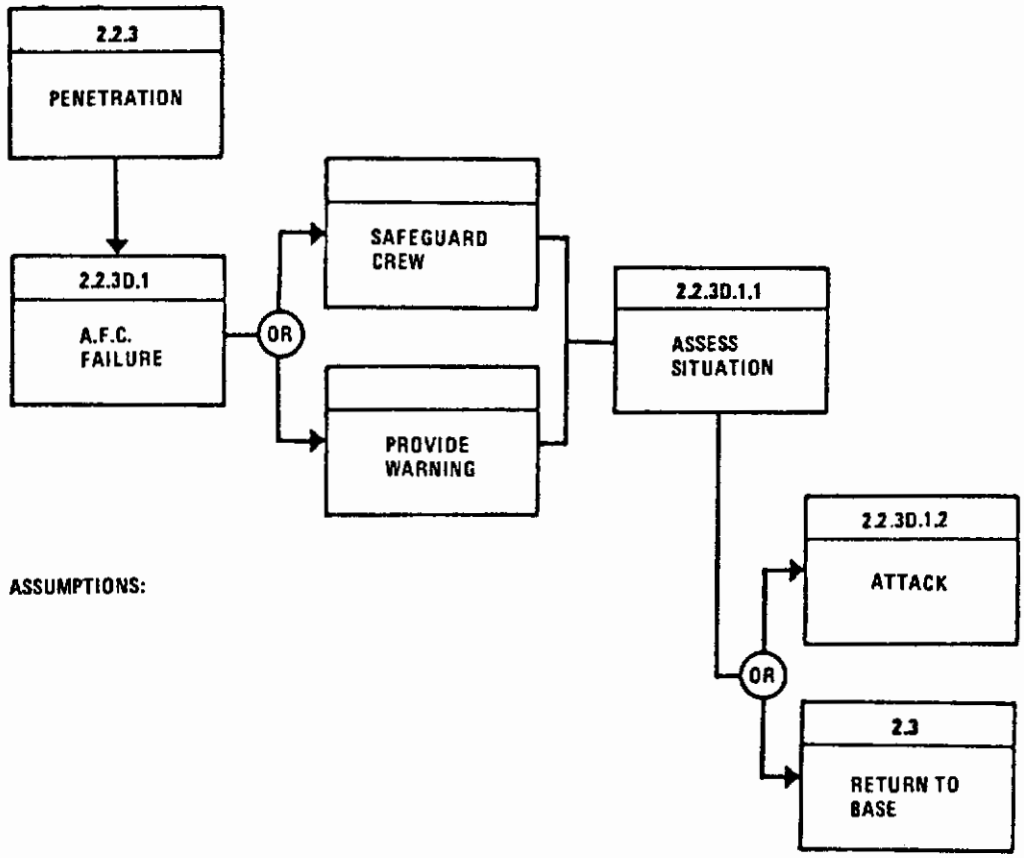


Figure 16. AFC Failure (L. L. Penetration)

Degraded Mode: AUTOPILOT FAILS – A/G COMBAT (PENETRATION)

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3 Air-to-Ground Combat (Low Altitude Penetration) 2.2.3D.1 Autopilot Failure		Assume: Autopilot engaging function fails.										
		1. Detect Failure 2. Warn crew. 3. Monitor warning and procedure.	1. Fault exists in AFCS 2. Visual, auditory 3. Preprogrammed instructions to crew	Master Caution, Voice, HUD/VSD MPD	(Storage) C/I Panel (FMAC Select)	 TNC	 3.0	Ref. 2.2.3 2.2.3.1 "Monitor & Control A/C"		Machine Machine Man/Machine	See revised Comm./Ident. Panel for radio comm.	
		4. safeguard crew. 5. Communicate and inform BAC	4. Preprogrammed action 5. Radio voice/DL modes avail.	MPD	(Storage) Comm./Ident. Panel	TNC	5.0	2.2.3.2 "Navigate" 2.2.3.5 "Monitor Enemy Activity"		Machine Man/Machine	See revised Comm./Ident. Panel for FMAC	
	2.2.3D.1.1 Assess Situation	Assumption: Preprogrammed action in (4) above provides for driving pitch trim motor "g" units nose up. Subsequent action follows:										
		1. Consider: System failed Alternate systems Mission environment TF/TA requirements Weapon del. requirements FMAC instructions		 MPD MPD HUD/VSD MPD		 10.0 10.0 10.0 10.0 10.0 10.0	 1.0 1.0 1.0 1.0 1.0 (included in (3 above		 3.0 3.0 3.0 3.0 3.0 3.0 3.0	 Man Man Man Man Man Man/Machine Man/Machine		
		2. Decision				10.0	2.0					
	2.2.3D.1.2 Continue Mission in Degraded Mode or 2.3 Return to Base	1. Reset master caution 2. Retrim aircraft to level flight 3. Perform manual flight	1. "Lite" illuminated. 2. Trim switch available. 3. Items	 HUD/VSD	Master Caution Panel Primary Flight Controller Stick and Throttle	TNC 5.0 3.0	1.5 3.0 2.0		2.0 2.0 2.0	Man Man/Machine Man/Machine		

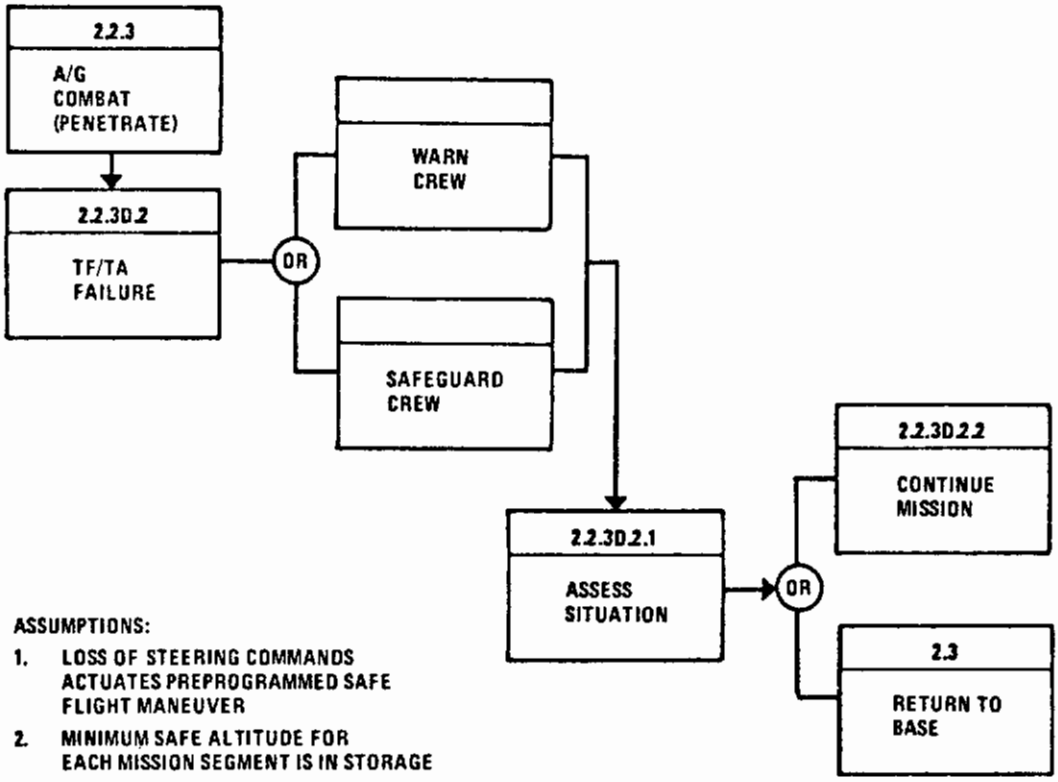


Figure 17. TF/TA Failure

Degraded Mode: TF/TA FAILURE - A/G COMBAT (L.L. PENETRATION)

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3 A/G Combat (Penetration)												
2.2.3D.2 TF/TA Failure		1. Detect failure. 2. Warn crew. 3 Safeguard crew. 4. Monitor warning and procedured.	1. Fault exists 2. Visual, auditory and tactile 3. Preprogrammed A/C climb 4. Preprogrammed instructions to crew	Master Caution, Voice, HUD/VSD MPD	No No	TNC	3.0	Ref. 2.23 "Provide Identity" "Monitor & Control A/C" "Monitor Enemy Activity"		Machine Machine Machine Man	Require means to shut off warning. Require means to insert minimum safe IFC alt. during TF/TA operation. Normally preprogrammed in storage.	Trade Study Master Caution Reset (Push Button Control) Keyboard "Items" Min' IFC Alt. Numeral XXX Enter
		5. Communicate and inform BAC.	5. Radio voice/DL modes avail.	MPD	Comm./Ident. Panel	TNC	5.0	" "		Man/Machine		
	2.2.3D2.1 Asses Situation	1. Consider: Type of failure Alternate systems Mission environment Instructions to crew TF/TA requirements 2. Decision	(See below - continue mission or return to base.)	MPD MPD MPD		15.0 15.0 15.0 15.0 15.0 15.0	2.0 2.0 1.0 (Included in (4) above) 2.0 2.0	" " " " " " " " " " " "	3.0 3.0 3.0 3.0 3.0 3.0	Man Man/Machine Man Man/Machine Man/Machine Man/Machine		
	2.2.3D2.2 Continue Mission at IFC Altitude	(See Min. IFC Alt. Trade Study above for manual IFC altitude change capability.) Note: When TFA/TA fails the aircraft will initiate an emergency climb and level off to a preprogrammed IFR MSL altitude. For example, 800 ft. above the highest peaks within a specified range. This altitude will be maintained until master caution reset button is depressed, and pilot takes over manual flight control.										
Ref. 2.3 Return to Base												

Degraded Mode: TF/TA FAILURE - A/G COMBAT (L.L. PENETRATION)

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Master Warning Reset	OPTION NO. 1 Push Button	OPTION NO. 2 Toggle Switch (spring loaded)	OPTION NO. 3 Keyboard	OPTION 4 Voice	SELECTION
CRITICALITY Medium	Pro:	Pro:	Pro:	Pro:	Option 1
FREQUENCY OF USE Medium	1. Could serve as master caution. 2. Rapid single-action. 3. Conforms with general design concept.	1. Separate caution signal required. 2. Rapid single-action.	1. No additional panel space required.	1. No panel space required. 2. No lighting required.	For degraded mode, voice control for normal mode.
RESPONSE TIME Medium	Con:	Con:	Con:	Con:	
PRECISION REQUIREMENTS High	1. Must be lighted. 2. Additional panel space required.	1. Must be lighted. 2. Additional panel space required.	1. Time required to make keyboard entry. 2. Must be lighted.	1. Complex. 2. Interferes with communications.	
ENVIRONMENT CONSTRAINTS					
LOCATION ALLOCATION					
VISION					
REACH Secondary					

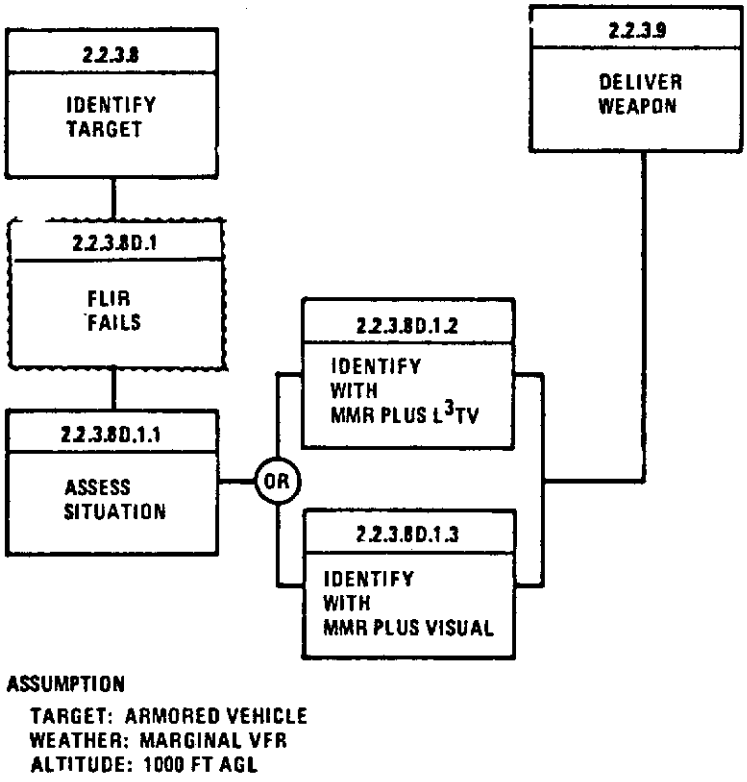


Figure 18. FLIR Fails During A/G Combat

Degraded Mode: L³TV/FLIR FAILS – AIR TO GROUND COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3.8 Identify Target		1. Slave L³TV/FLIR to computer line-of-sight	1. Sensor coincidence (common pointing)		No	TNC	1.5	Ref. 2.2.3.1 "Monitor & Control A/C"	2.0	Men/Machine	Require method of slaving L³TV/FLIR to CCC line-of-sight.	Push button control: Boresight Stow Independent (See trade study sheet)
		2. Select desired field of view.	2. Wide or narrow		Aux. E-O Sensor Control	TNC	1.5	" "	2.0	Men		
		3. Select moving targets with E-O sensors.	3. L³TV/FLIR MTI switching mode		No	TNC	1.5	" "	2.0	Men/Machine	Require addition of MTI to existing L³TV/FLIR makes.	
		4. Search for targets in field of view.	4. Targets available, target contrast	HUD/VSD		TNC	3.0	" "	2.0	Men		Use L³TV/FLIR MTI push button on Radar Mode Select Panel.
2.2.3.8D.1 L³TV/FLIR Fails		1. Detect failure.	1. Fault exists			TNC		" "		Machine		
		2. Warn crew.	2. Visual, auditory	Master Caution Voice, HUD/VSD		TNC	2.0	" "	2.0	Men/Machine		
		3. Monitor FMAC/CCC instructions.	3. Preprogrammed instructions to crew	MPD		TNC	3.0	" "	2.0	Men		
		4. Shut down system	4. Programmed procedures		(Storage) Comm./Ident.	TNC		" "	2.0	Machine		Note: Keyboard is secondary means of shutting down system.
		5. Communicate with Battle Area Controller.	5. Radio position, modes (SEC voice, D/L)	MPD	Panel and Microphone	TNC	5.0	" "	2.0	Men/Machine		
	2.2.3.8D.1.1 Assess Situation	1. Consider: Fault				15.0	2.0	" "	4.0	Men/Machine		
		Environment				15.0	1.0	" "	4.0	Men		
		Terrain				15.0	2.0	" "	4.0	Men		
		Enemy defenses				15.0	2.0	" "	4.0	Men/Machine		
		Friendly A/C in area				15.0	1.0	" "	4.0	Men		
		FMAC/CCC instructions and alternate systems				15.0	(Included in I3 above)	" "	4.0	Men/Machine		
		BAC instructions (if available)										
		2. Decision				15.0	2.0	" "	4.0	Men/Machine		
	2.2.3.8D.1.2 Identify Target with MMR and IFF	1. Select MMR mode and desired presentation.	1. MMR MTI mode, Rx gain, display range (variable)			15.0	3.0	" "		Men	Note: Rx gain permits background shading during MMR MTI mode as an aid to target location and identification.	
		2. Select type scan	2. " PPI or OCS**			15.0	1.5	" "		Men		
		3. Search and acquire moving targets.	3. Moving targets available, range, bearing			15.0	3.0	" "		Men		
		4. Designate target.	4. Cursor enable, directional control, lock-on.	HSD	Designation Control/Voice	15.0 sec Total	3.0	Ref. 2.2.3.1 "Monitor & Control A/C"	3.0	Men	Note: It is assumed in the 1980 time period all vehicles behind enemy lines will have means to communicate on secure frequencies.	
		5. Interrogate with Directional Communication.	5. Comm./Ident. interrogate available (spread spectrum).		No	"	1.5	"Monitor Enemy Activity"	3.0	Men/Machine		
		6. Identify target from sensor data.	6. Target enhancement modulation	HSD	No	"	2.0	" "	3.0	Men/Machine	Require means to interrogate with secure communications.	Comm./Ident. Panel Push button control Comm./Ident. Interrogate
		or if unable to identify target with MMR/IFF combination.									Require means for visual response to interrogation.	Interrogation status Activate Response
	2.2.3.8D.1.3 Identify Target with MMR+Visual	Same as 1 through 4 above with addition of performing visual identification through the windscreen.										
Ref. 2.2.3.9 Deliver Weapon			* PPI – Plan Position Indicator ** OCS – Off Center Sector									

Degraded Mode: FLIR FAILS DURING AIR TO GROUND COMBAT

DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS Synchronize all sensors to a common line-of-sight.	OPTION NO. 1 Voice commands to FCS.	OPTION NO. 2 Integrated keyboard control (IKC).	OPTION NO. 3 Illuminated push buttons.	SELECTION	
CRITICALITY High FREQUENCY OF USE Low RESPONSE TIME Medium PRECISION REQUIREMENTS None ENVIRONMENT CONSTRAINTS LOCATION ALLOCATION VISION Primary REACH Primary	Pro: 1. Requires little physical movement other than voice/keyboard changeover. Con: 1. Still requires a switch action to enter "Voice" control. 2. Requires a special voice imprint card for every pilot. 3. Complex. 4. May interfere with external voice communication.	Pro: 1. Hand can stay in common area to perform similar FCS tasks. 2. Compatible with digital equipment. 3. Saves space. Con: 1. Takes more time than a single switch or push button control. 2. Slaving status is not apparent until FCS is selected on master keyboard select panel.	Pro: 1. Simple motion. 2. Ease of operation with glove hand. 3. Position can be easily identified. 4. Compatible with other CCC moding and data link equipment. Con: 1. Lamps may fail. 2. Must be looked at to operate.	Option 3 Illuminated push buttons with "Boresight," "Stow," or "Independent" in a readily accessible area. Normal switch position will "Boresight." Note: "Boresight" mode will be the normal switch position which synchronizes all radar and electro-optical sensors to a common line-of-sight. L^3TV/FLIR sensor pointing angles will stow at "0" azimuth and elevation angles on "Stow" command. In the "Independent" mode the L^3TV/FLIR pointing angles will be slaved independently of the radar corsshair when directed by the tracking control.	

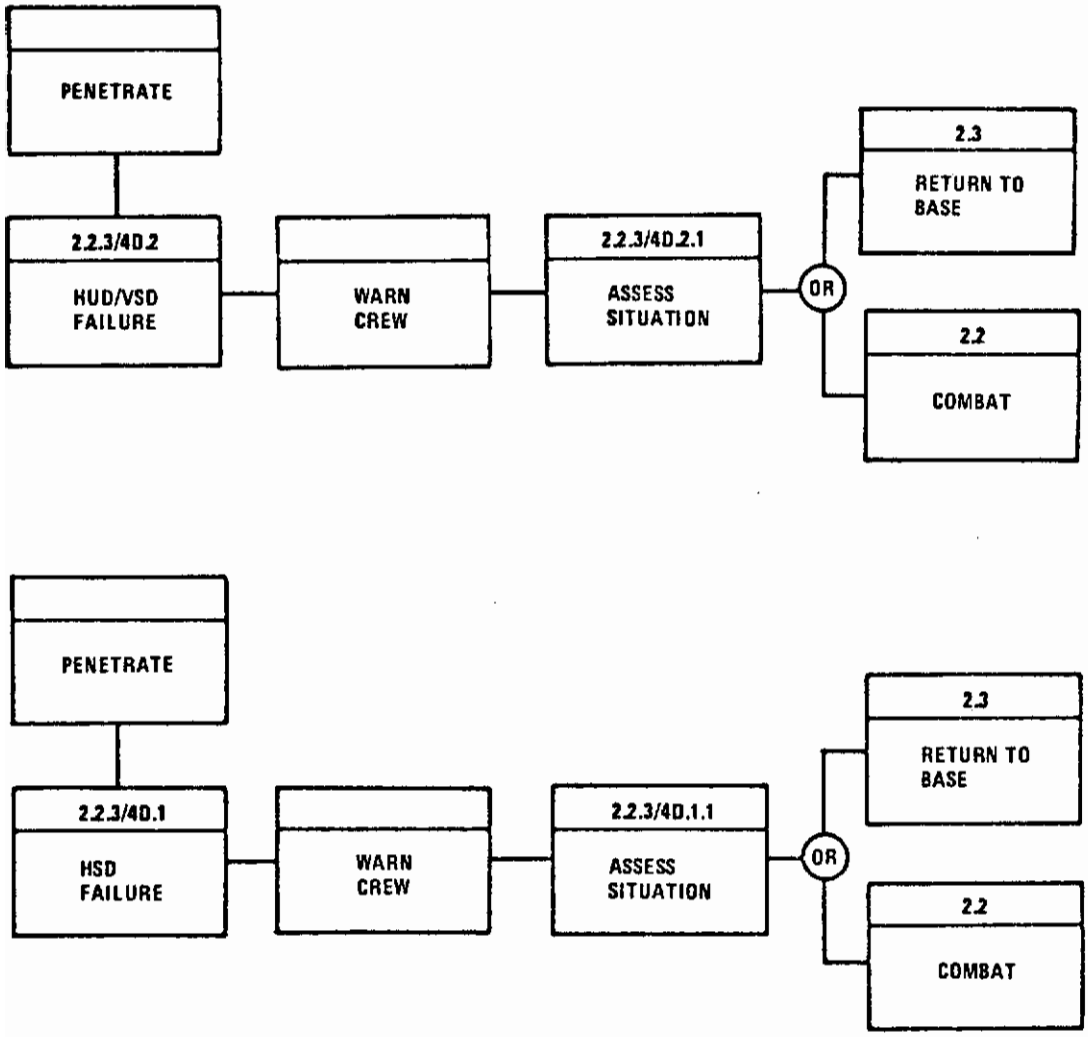


Figure 19. HUD/VSD Failure

Degraded Mode: HUD/VSD FAILURE – AIR-TO-AIR/GROUND COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3/4 Air-to-Air Air-to-Ground Combat												
2.2.3/4D.2 HUD/VSD Fails		1. Detect failure.	1. Fault exists									
		2. Warn crew	2. Visual, auditory, tactile	Master Caution Voice/HUD/VSD	(Storage)	3.0	1.0	Ref. 2.2.3/4 "Navigate"	3.0	Machine Man/Machine		
		3. Monitor FMAC instructions	3. Preprogrammmed N instructions	MPD		3.0	3.0	"Provide Identity" "Monitor Enemy Activity"	3.0	Man		
		4. Communicate and inform BAC	4. Radio modes avail. (voice, D/L)	MPD	Comm./Ident. Panel	TNC	5.0	" "	3.0	Man/Machine		
	2.2.3/4D.2.1 Assess Situation	1. Consider:									Requirement: HUD/VSD data to be automatically presented on MPD No. 2 upon failure because task time required exceeds task time available.	
		Fault				3.0	2.0	Same as 2.2.3/4 above.	3.0			
		Environment				3.0	2.0	" "	3.0			
		TF/TA requirements				3.0	1.0	" "	3.0			
		Alternate displays				3.0	1.0	" "	3.0			
		FMAC instructions				3.0	(Included in 3 above)	" "	3.0			
		2. Decision				3.0	2.0	" "	3.0		Recommend: Format selection for MPD No. 2 must always contain automatic/manual HUD/VSD transfer capability. Use the following procedure to preprogram MPD.	
	2.2.3/4D.2.2 Select Alternate Displays (Auto/ Manual)	1. Present HUD/VSD information on MPD	1. Preprogrammed HUD/VSD info. to assigned MPD as priority No. 1		(CCC * Storage)			Same as 2.2.3/4 above.		Machine		
		2. Inform crew	2. N instructions	MPD		2.0	2.0	" "	1.0	Man/Machine		Keyboard
		3. Observe data, or manual:	3. Primary items data with attitude	MPD		TNC	2.0	" "	1.0	Man		"C/D" MPD No XX HUD/VSD Transfer Enter
		4. Select MPD for HUD/VSD info.	4. MPD available for HUD/VSD information		No	3.0	5.0	" "	1.0			
		5. Observe HUD/VSD information.	5. HUD/VSD symbology	MPD Selected		3.0	2.0	" "	1.0		Note: Subsequent action required for rapid transfer of HUD/VSD information to MPD as follows:	
Ref. 2.3 Return to Base Ref. 2.2 Combat												1. Select MPD No. 2 2. Activate HUD/ VSD transfer PB.

*CCC – Central Computer Complex

Degraded Mode: HSD FAILURE – ATTACK/COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3/4 Attack/Combat												
2.2.3/4D.1 HSD Fails		1. Detect failure	1. FMAC detects deteriorating signals	Master Caution				Ref. 2.2.3/4 "Navigate" and "Monitor		Machine		
		2. Warn crew	2. Visual, auditory	Voice, VSD/HUD	(Storage)	5.0	1.0	Enemy Activity"	2.0	Man/Machine		
		3. Monitor FMAC instructions	3. Programmed msg. in storage	MPD		5.0	3.0	" "	2.0	Man		
		4. Communicate and inform	4. Radio modes available (voice, D/L)	MPD	Comm./Ident. Panel	TNC	(Optional)	" "	2.0	Man/Machine		
	2.2.3/4D.1.1 Assess situation	1. Consider: Fault; Environment; Mission Requirements; Alternate Displays; FMAC Instructions						" "				
		2. Decision						" "				
	2.2.3/4D.1.2 Select alternate displays (Auto/ Manual)	1. Take corrective action to prevent subsequent system damage.	1. Affected display shutdown		FMAC/CCC			" "		Machine		
		2. Transfer HSD information to VSD and transfer VSD information to HUD.	2. HSD transfer function available		No		1.5	" "	2.0	Man/Machine	Redesign IIPACS I for greater flexibility among primary displays	Push Button Control "HSD Transfer" On
		3. Observe HSD information or manual:	3. HSD symbology/video				2.0	" "	2.0	Man		
		4. Select MPD for HSD information.	4. MPD available for HSD info.		No		5.0	" "	2.0	Man/Machine	Redesign IIPACS I MPD format	
Ref. 2.3 Return to Base		5. Observe HSD information.	5. HSD symbology/video	MPD Selected			2.0	" "	2.0	Man	to provide greater flexibility and more rapid operation	Keyboard "C/D" HSD Transfer HSD to MPD No. XX Enter
Ref. 2.2 Combat											Note: Recommend changing No. 5 el type display to same as MPD 1 through 4	

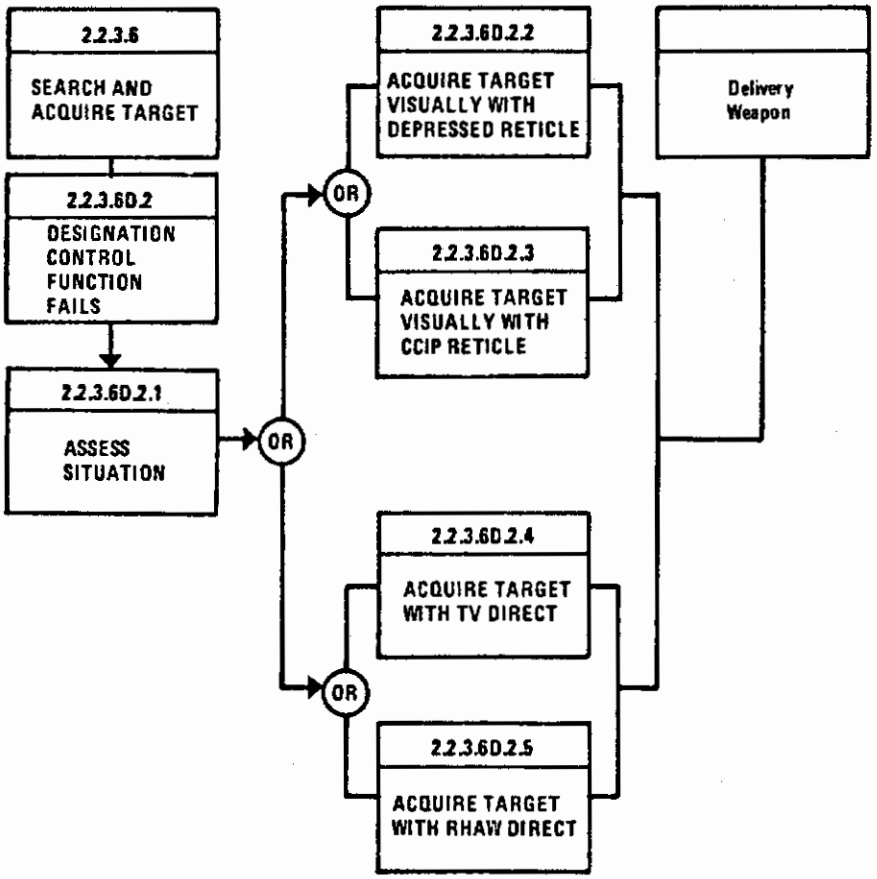


Figure 20. Designation Control Function Fails During Air-To-Ground Weapon Delivery

Degraded Mode: DESIGNATION CONTROL FAILS – AIR-TO-GROUND COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3.6 Target Search and Acquisition												
2.2.3.6D.2 Designation Control Function Fails (Voice and Control Stick)		1. Detect failure. 2. Warn crew.	1. Fault exists 2. Visual, auditory	Master Caution, Voice, HUD/VSD	(Storage)	5.0	1.0	Ref. 2.2.3 "Monitor & Control A/C" "Navigate," "Provide Identity" and "Monitor Enemy Activity"	3.0	Machine Man/Machine	Add "EMAC Warn" volume control to comm./ident. panel.	
		3. Monitor FMAC instructions.	3. Preprogrammed msg. in storage	MPD		5.0	3.0		3.0	Man		
	2.2.3.6D.2.1 Assess Situation	1. Consider: Fault				15.0	2.0	" "	4.0	Man		
		Alternative controls				15.0	2.0	" "	4.0	Man		
		Accuracy requirements				15.0	2.0	" "	4.0	Man		
		Target type				15.0	2.0	" "	4.0	Man		
		Environment				15.0	2.0	" "	4.0	Man		
		FMAC instructions				15.0	(Included in (3 above)	" "	4.0	Man		
		2. Decision				15.0	2.0	" "	4.0	Man		
	2.2.3.6D.2.2 Perform Manual Depressed Reticle Bombing (Ballistics Weapon)	1. Select and monitor weapon.	1. Stores available and status		SMS Panel	20.0	1.5	Ref. 2.2.3 "Provide Identify" and "Monitor Enemy Activity"	5.0	Man	Note: Assume at least one program has been selected for each store – prior to takeoff.	
		2. Select delivery method.	2. Depressed reticle		No	20.0	1.5		5.0	Man		
		3. Select delivery maneuver.	3. Dive, toss, level, OTS, etc.		No	20.0			5.0	Machine	SMS – Add "Depressed Reticle" to keyboard	
		4. Select type release.	4. Manual/auto		SMS Panel	20.0	1.5	" "	5.0	Man		
		5. Select primary flight phase.	5. Air-to-ground combat			20.0	1.0	" "	5.0	Man		
		6. Insert mil settings.	6. ± mil depression	HUD/VSD	Keyboard	20.0	3.0	" "	5.0	Man	SMS – Add "Delivery Maneuver" with options to existing keyboard	
		7. Locate target – moving or fixed.	7. Target detected by visual/ visual aided sensors.	HUD/VSD		20.0	4.0	" "	5.0	Man/Machine		
		8. Maneuver aircraft for attack.	8. Items (pitch and roll commands)		No	20.0	3.0	" "	5.0	Man/Machine	Use existing AFCS panel for control stick steering (CSS). Revise AFCS panel to include this type steering any time autopilot is "On."	
		9. Position pipper on target.	9. Target visible, depressed reticle visible	HUD/VSD		20.0	3.0	" "	5.0	Man/Machine		
		10. Perform manual delivery maneuver and monitor parameters.	10. Dive angle, EAS, release altitude	HUD/VSD	AFCS/Manual (See (8) above)	20.0	(Continuous to release point)	" "	5.0	Man/Machine		

Degraded Mode: DESIGNATION CONTROL (VOICE & CONTROL)

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
	2.2.3.6D.2.3 Perform CCIP(1) Bombing (Ballistic Weapon)	1. Select weapon. 2. Select delivery method. 3. Select delivery maneuver. 4. Select type release. 5. Select desired CEP. 6. Locate target. 7. Maneuver A/C and position CCIP reticle on target.	1. Stores available and status 2. CCIP 3. Dive, level, toss 4. Manual release available 5. CEP mil settings 6. Sensors and modes available 7. Target located and identified	HUD/VSD HUD/VSD	SMS Panel No Keyboard Control SMS Panel No Primary Flight Control	15.0 15.0 15.0 15.0 15.0 15.0 15.0	1.5 3.0 1.5 3.0 3.0	Ref. 2.2.3 "Provide Identity" "Monitor Enemy Activity" " " " " " " " "	4.0 4.0 4.0 4.0 4.0 4.0 4.0	Man Man Machine Man Machine Man/Machine Man/Machine	"SMS" – Add CCIP to delivery method on Keyboard Control. "SMS" – Size of CCIP reticle will be preset (20, 30, 40 mil, etc.). However, keyboard has provisions for setting any reticle size. Called "Allowable Mil Accuracy Symbology."	
	2.2.3.6D.2.4 Acquire Target with TV Direct (TV Missile)	1. Select weapon. 2. Select delivery method. 3. Select delivery maneuver. 4. Select type release. 5. Monitor WPN TV caging. 6. Monitor WPN TV video. 7. Maneuver A/C to acquire target. 8. Uncage TV guidance.	1. Stores available and status 2. WPN TV 3. Conversion 4. Manual 5. Cage/uncage status 6. Adequate signal level 7. Items (pitch and roll) 8. Contrast lock-on	MPD HUD/VSD HUD/VSD	SMS Panel No Keyboard Control SMS Panel No Primary Flight Control No	15.0 15.0 15.0 15.0 15.0 15.0 15.0 15.0	1.5 3.0 1.5 1.0 1.0 3.0 1.5	" " " " " " " " " " " " " " " "	4.0 4.0 4.0 4.0 4.0 4.0 4.0 4.0	Man Man Machine Man Man Man Man/Machine Man	"SMS" – Add WPN TV to delivery method on existing keyboard. Require means for WPN TV "Contrast Lock-on."	Designation Control o Lock-on/Reject E-O Aux. Sensor Control o Contrast L.O. (Secondary means of L.O.)
	2.2.3.6D.2.5 Acquire Target with RHAW Direct (Anti-Radiation Missile)	1. Select weapon. 2. Select delivery method. 3. Select delivery maneuver. 4. Select type release. 5. Monitor RF threat and position data. 6. Steer to "zero" pointer. 7. Monitor launch parameters.	1. Stores available and status 2. ARM(2) delivery 3. Conversion 4. Automatic or manual 5. RF strobes, bearing, approx. range 6. Items (pitch and roll) 7. Range-to-go, altitude, speed	BSD/HSD HUD/VSD HUD/VSD	SMS Panel No Keyboard Control SMS Panel Primary Flight Controller 	15.0 15.0 15.0 15.0 15.0 15.0 15.0	1.5 3.0 1.5 3.0 3.0 1.0	" " " " " " " " " " " " " "	4.0 4.0 4.0 4.0 4.0 4.0 4.0	Man Man Machine Man Man Man/Machine Man	"SMS" – Add ARM to Delivery Method select on keyboard.	

(1) CCIP – Continuously Computed Impact Point
(2) ARM – Anti-Radiation Missile

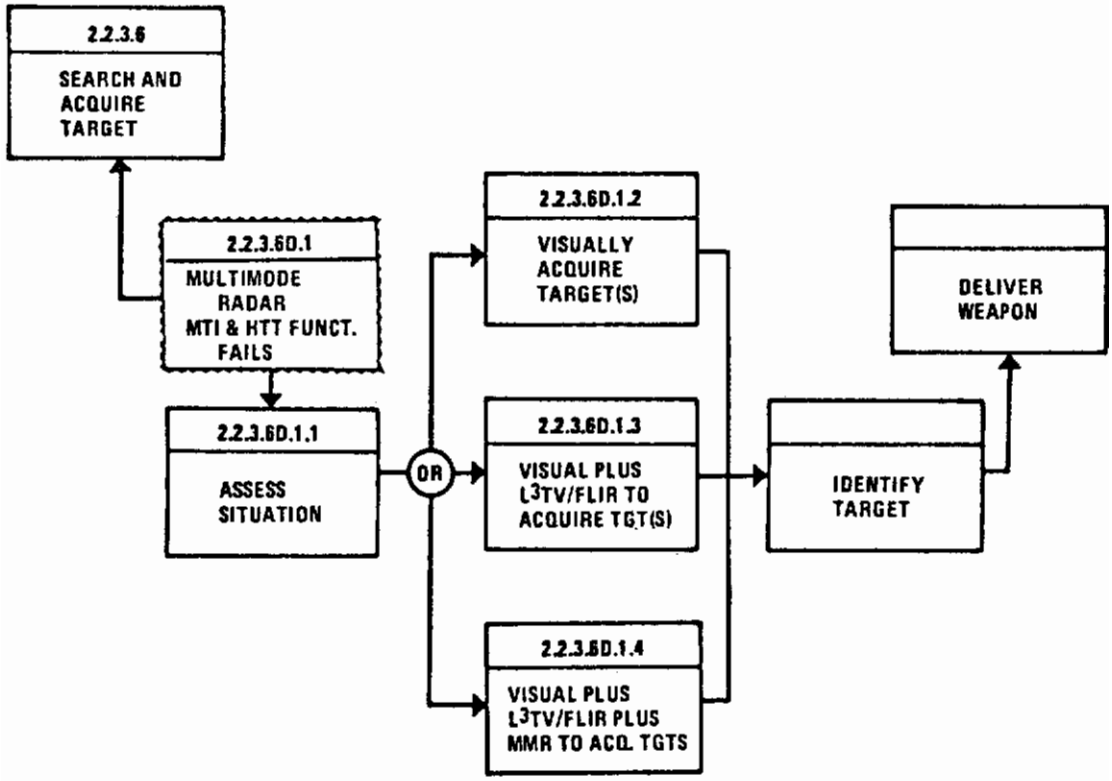


Figure 21. Multimode Radar MTI/HTT Mode Function Failure

Degraded Mode: MULTIMODE RADAR MTI[1] AND HTT[2] FUNCTIONS FAIL – A/G COMBAT

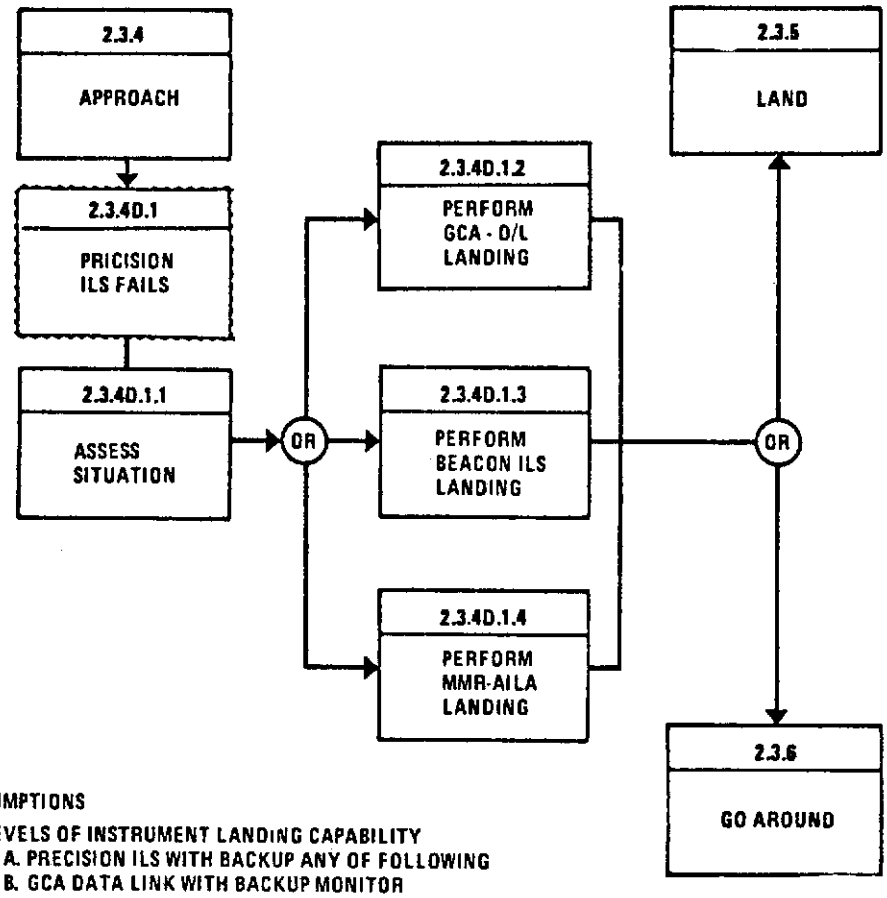
FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3.6 Target Search and Acquisition		1. Select ATA[3] mode. 2. Select moving target. 3. Select desired range. 4. Monitor displays for targets.	1. MMR[4], L^{3}TV & FLIR sensors avail. 2. Moving vehicle threats in area. 3. 0-30 nm range @ low altitude 4. Targets symbolically displayed.	HUD/VSD/HSD	No No Aux. Radar/Map Control Panel	TNC	2.0 2.0 2.0 5.0	Monitor & Control A/C & Monitor Enemy Activity " " " "	3.0 3.0 3.0 3.0	Man Man Man Man	Require means to select any A/A or A/G target. Only those targets selected shall be displayed to crew.	Keyboard "FCS"–ATA • Target Selection (trucks, tanks, trains, etc)
2.2.3.6D.1 Multimode Radar MTI and HTT Functions Fail		1. Detect failure. 2. Warn crew. 3. Monitor FMAC instructions. 4. Communicate and inform BAC.	1. Fault exists. 2. Visual, auditory. 3. Preprogrammed msg. in storage. 4. Radio modes (secure, voice and D/L) available.	Master Caution, Voice, HUD/VSD MPD MPD	Comm./Ident. Panel & Throttle Microphone	15.0 15.0 15.0 15.0	2.0 3.0 5.0	" " " " " " " "	3.0 3.0 3.0	Machine Man/Machine Man Man/Machine	Provide warning when "Mission Critical" systems fail.	See trade sheet. • Warning Light (Master Caution) • Blink Symbols on HUD/VSD • Voice Warning
	2.2.3.6D.1.1 Assess Situation	1. Consider: Fault Remaining sensors Type threats Weather environment Terrain Friendly A/C in area Instructions from FMAC 2. Make decision.	System failed Sensors on board Mission scenario Forecasted WX Map of area Mission scenario and comm.	MPD MPD HSD/BSD MPD HSD (Map) HSD/BSD MPD		TNC TNC TNC TNC TNC TNC TNC TNC	2.0 2.0 2.0 1.0 2.0 2.0 (included in (3) above) 2.0	Monitor & Control A/C & Monitor Enemy Activity " " " " " " " " " " " "	6.0 6.0 6.0 8.0 6.0 6.0 6.0 6.0	Man Man Man Man Man Man Man Man		
	2.2.3.6D.1.2 Visually Acquire Target(s)	1. Descend to visual altitude. 2. Alter course. 3. Perform visual search.	1. Items, absolute altitude 2. Heading/ground track 3. Windscreen visibility during VFC	HUD/VSD/MPD HUD/VSD	No Primary Flight Control	TNC TNC TNC	5.0 3.0 10.0	Monitor Enemy Activity & Navigate " "	6.0 6.0 6.0	Man/Machine Man/Machine Man	Provide airspeed and altitude commands for items. Provide airspeed and altitude capture.	See revised keyboard items. • CMD altitude • CMD airspeed See revised AFCS panel • Altitude capture • Airspeed capture
	2.2.3.6D.1.3 Perform Visual Plus L^{3}TV/FLIR to Acq. Target(s)	1. Descent to visual altitude. 2. Select MMR "Beacon" 3. Deactivate ATA mode. 4. Select E-O[5] sensors. 5. Select field of view 6. Adjust display for maximum contrast level between targets and background.	1. Items + absolute altitude 2. Beacon mode available. 3. ATA mode switching 4. L^{3}TV/FLIR available 5. Wide/narrow FOV 6. Intensity and contrast controls available.	HUD/VSD/MPD	Radar Mode Select Panel Keyboard No E-O Aux Sensor Control No	TNC TNC TNC TNC TNC TNC	5.0 1.5 3.0 3.0 3.0 3.0	" " " " " " " " " " " "	5.0 5.0 5.0 5.0 5.0 5.0	Man/Machine Man Man Man Man Man/Machine	Require means to select individual sensors. Require means to adjust display intensity and contrast.	See revised sensor/ display select panel • FLIR • L^{3}TV See level control panel • Intensity • Contrast • HUD/VSD/HSD/ MPD–1 through MPD–5

(1) MTI – Moving Target Indication
(2) HTT – Hard Target Tracking
(3) ATA – Auto Target Acquisition
(4) MMR – Multi Mode Radar
(5) E-O – Electro-optical

Degraded Mode: FAIL MULTIMODE RADAR MTI & HTT MODE FUNCTIONS DURING A/G COMBAT

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.2.3.7 Prepare for Combat	2.2.3.6D.1.3 (continued)	7. Select E-O to boresight position. 8 Select E-O MTI mode. 9. Locate downed airman. 10. Designate cursor on airman. 11. Search for moving vehicle threats in near vicinity of airman.	7. Stow/BS[1] position avail. 8. Moving targets @ > 5 nm relative ground velocity 9. Coded beacon returns 10. Target and crosshairs 11. Ground targets (moving) available, target-sensor matching	 HUD/VSD/HSD HUD/VSD/HSD HUD/VSD/HSD	No No Designation Control	TNC TNC TNC TNC TNC	2.0 2.0 10.0 5.0 10.0	Monitor & Control A/C & Monitor Enemy Activity & Performing Navigation " " " " " "	6.0 6.0 6.0 6.0 6.0	Man Man Man Man Man/Machine	E-O BS/Stow position MTI selection for L³TV & FLIR.	See trade sheet. E-O Auxiliary Control Panel o Stow o Boresight/ individual
	2.2.3.6D.1.4 Perform Visual Plus L³TV/FLIR Plus MMR to Acq. Target(s)	1 thru 11 - Same as above 12. Select MMR high resol. GM[2] mode. 13. Select MMR HRGM[3] search area. 14. Monitor radar display. 15. Monitor moving map display. 16. Monitor E-O display. 17. Correlate position & threat data from all displays. 18. Locate threat(s) 19. Designate threat.	See 1-11 above. 12. MMR "Spotlight" mode avail. 13. 1 x 1, 2 x 2, or 4 4 x 4 nm 14. HRGM details 15. Topographical & cultural detail 16. Video & contrast levels 17. Target-sensor matching, MTI video & detailed maps of area 18. Symbology 19. Crosshair position control in 360° az.	 HSD HSD/Map HUD/VSD HUD/VSD/HSD HUD/VSD/HSD Designation Controller	 No No 	 30.0 30.0 30.0 30.0 30.0 30.0 30.0 30.0	 2.0 2.0 3.0 5.0 5.0 (Included in above) (Included in above) 5.0	 " " " " " " " " " " " " " " " "	 6.0 6.0 6.0 6.0 6.0 6.0 6.0 6.0	 Man Man Man Man Man Man Man/Machine Man/Machine	Require: MMR "Spotlight" function. Require: Search area for "Spotlight" mode. Require means to designate targets.	See revised Radar Mode Select Panel. o TV/FLIR MTI See revised Radar Mode Select Panel. o Add "Spotlight" Keyboard "FCS-MMR" o Add 1x1,2x2 or 4x4 nm search area See new Desig. Control. o Enable o Range,az,&elev. o Lock on/reject

(1) BS - BORESIGHT
(2) GM - Ground Map
(3) HRGM - High Resolution Ground Map



ASSUMPTIONS

1. LEVELS OF INSTRUMENT LANDING CAPABILITY
   - A. PRECISION ILS WITH BACKUP ANY OF FOLLOWING
   - B. GCA DATA LINK WITH BACKUP MONITOR
   - C. BEACON ILS WITH BACKUP MONITOR
   - D. MMR WITH BACKUP MONITOR
2. RUNWAY SIZE 5000 FT X 50 FT
3. RUNWAY CONTAINS BURIED CABLE FOR ROLLOUT AND TAXI GUIDANCE
4. FAILURE OCCURS BEFORE 60 SEC TO TOUCHDOWN - OTHERWISE, GO AROUND
5. WEATHER MINIMUMS AT 3C
6. AUTO OR MANUAL LANDING CAPABILITY EXISTS FOR ANY OF FOUR LANDING SYSTEMS

Figure 22. Precision ILS Fails

Degraded Mode: PRECISION ILS FAILURE – APPROACH

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.3.4 Approach												
2.3.4D.1 Precision ILS Fails		1. Detect failure. 2. Warn crew. 3. Disconnect autopilot and hold attitude. 4. Monitor FMAC instructions. 5. Communicate with approach/final controller.	1. Fault exists 2. Visual, auditory. 3. Stored logic procedure. 4. Preprogrammed msg. to crew. 5. Radio comm. available (position, voice).	Master Caution, Voice, HUD/VSD (Storage) MPD MPD	Comm./Ident. Panel & Mic.	5.0 5.0 5.0 5.0 5.0	1.0 3.0 (Optional)	Ref. 2.3.4 "Approach" Monitor & Control A/C, Navigate & Provide Identity " "	2.0 2.0 2.0 2.0 2.0	Machine Man/Machine Machine Man Man/Machine	See revised Comm./Ident. Panel FMAC • Warning • Volume Control See revised Comm./Ident. Panel Position XX Mode XX Transmit/Receive	
	2.3.4D.1.1 Assess Situation	1. Consider: Fault Environment Alternate systems Accuracy requirements Runway width and length FMAC instructions 2. Decision				10.0 10.0 10.0 10.0 10.0 10.0 10.0	2.0 1.0 2.0 1.0 1.0 (Included in (4) above) 2.0	" " " " " " " " " " " " " "	2.0 2.0 2.0 2.0 2.0 2.0 2.0			
	2.3.4D.1.2 Perform GCA-D/L Landing	1. Switch to GCA D/L as primary landing system. 2. Monitor flight dir. needle commands. 3. Monitor primary and backup system video/mapping. 4. Engage autopilot and continue approach.	1. GCA D/L available. 2. Pitch and roll commands (items). 3. GCA – D/L, MMR and moving map available. 4. Autopilot engage control available.	VSD VSD, HSD & MPD	No No	15.0 15.0 15.0 15.0	(Allow 3.0 sec if manual) 2.0 3.0 1.5	" " " " " " " "	3.0 3.0 3.0 3.0	Man/Machine Man Man Man	Requires means to select any alternate landing system. Requires means to engage autopilot in pitch and roll axis during land.	Use keyboard control. Select "NAV," ILS, GCA-D/L, Enter. Flight Mode Select • To/Land AFCS Panel • Autopilot On/Off Note: Steer aircraft manually until pitch and roll signals are available–then engage autopilot.

Note: GCA D/L may be primary system for landing at some bases. When this occurs, the AFCS may be remotely engaged and automatically coupled in pitch and roll for steering and guidance to a safe landing. The only requirement is: the autopilot switch must be manually engaged to "On" for concert reasons.

Degraded Mode: PRECISION ILS FAILURE – APPROACH

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
(Cont.)							(Allow 3.0 sec if manual)					
	2.3.4D.1.3 Perform Beacon ILS Landing (ILM)	1. Switch to beacon ILS as primary landing system.	1. Beacon ILS available.		No	15.0		Ref. 2.3.4 "Approach"	3.0	Man/Machine	Requirement exists to manually select alternate landing systems.	Using keyboard select "NAV"-then "BCN ILS" and "ENTER"
		2. Monitor flight dir, needle commands.	2. Pitch and roll steering commands.	VSD/HUD		15.0	2.0	Communicate & Provide Identity	3.0	Man		
		3. Monitor primary and backup system displays.	3. Beacon, MMR and moving map available.	VSD/HUD, HSD & MPD		15.0	2.0	" "	3.0	Man		
		4. Insert glide slope index.	4. GS selection available.		No	15.0	2.0	" "	3.0	Man	Require means to select desired glide slope angle.	Using keyboard select "NAV," "ILS & GS Angle," "Numerics," "Enter,"
		5. Engage autopilot and continue approach.	5. Autopilot pitch and roll available.		No (See 2.3.4D.1.2 above)	15.0	1.5	" "	3.0	Man		
	2.3.4D.1.4 Perform MMR-AILA Landing	1. Switch to MMR as primary landing system.	1. AILA mode available. TF/TA mode available.		No	20.0	3.0	" "	6.0	Man	Requirement exists to manually select MMR-AILA mode.	Use keyboard and select "NAV," "ILS," "AILA," "Enter"
		2. Switch to offset and track pre-programmed target in vicinity of runway.	2. Offset distance inserted and prominent target available.		No	20.0	4.0	" "	6.0	Man	Requirement exists to insert offset in CCC and enter offset.	
		3. Insert glide scope index.	3. 2-15° as desired.		No	20.0	2.0	" "	6.0	Man	See 2.3.4D.1.3 above.	Use keyboard and select "NAV," "INS-1 or INS No. 2 Offset No.," "Numerics," "Enter"
		4. Insert TF/TA C.P.	4. At least -100 ft. setting to clear any obstacle during approach.		Keyboard Control	20.0	3.0	" "	6.0	Man		
		5. Monitor flight dir, needle commands.	5. Pitch and az. steering commands and symbology.	VSD		20.0	2.0	" "	6.0	Man		
		6. Monitor backup nav. system display.	6. Moving map with A/C present and predicted ground position.	HSD		20.0	3.0	" "	6.0	Man		
		7. Reconnect autopilot and continue approach.	7. Autopilot pitch and roll available.		No (See 2.3.4D.1.2 above)	20.0	1.5	" "	6.0	Man		
Ref. 2.3.5 Land or Ref. 2.3.6 Go around		Note: When MMR-AILA mode is used for landing, allow at least 85 sec. time to touchdown in order to accomplish all tasks-otherwise go around.										

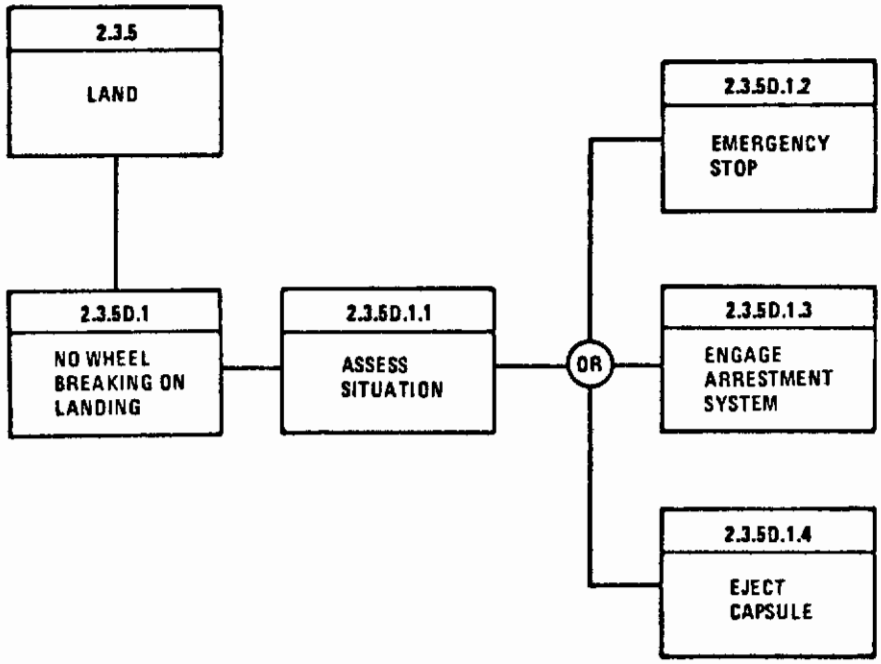


Figure 23. Brake Failure

Degraded Mode: WHEEL BRAKING FAIL – LAND

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT REQD. SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Ref. 2.3.5 Land		Note: For purposes of this analysis assume main and emergency brakes have failed, or because of icing conditions, braking effect is nonexistent.										
2.3.5D.1 Wheel Braking Fails		1. Detect failure. 2. Warn crew. 3. Monitor warning and procedures. 4. Communicate and inform.	1. Fault exists 2. Visual, auditory and tactile 3. Preprogrammed instructions to crew 4. Radio voice available (voice)	Master Caution, Voice, HUD/VSD MPD MPD	(Storage) Comm./Ident. Panel Microphone	1.0 2.0	1.0 2.0 3.0	Ref. 2.3.5 "Land" Vol. II " " " "	2.0 2.0	Machine Man/Machine Man Man/Machine	Require: Voice, visual and tactile warning on all systems which affect safety of flight. Note: FMAC senses brake pressure application when LG is lowered and provides audio/visual/tactile warning. FMAC senses anti-skid failure when wheel rotation activates anti-skid. FMAC senses brake failure and CCC provides alternate emergency brakes.	
	2.3.5D.1.1 Assess Malfunction	1. Consider: • WX environment • Runway conditions • Runway dimensions • Obstacles • Alternate braking systems • FMAC instructions • Tower instructions 2. Decision	VFR/IFR conditions Wet/dry/icy Runway Length/width Buildings, other A/C, etc. Thrust reversers, arrestment devices Normal/emergency Preworned knowledge of braking condition					" " " " " " " " " " " " " " " "				
	2.3.5D.1.2 Emergency Stop (Abort)	1. Activate abort switch. Reference: 2.1.1D.1.2 "Abort T.O." for Sequence of Events	1. Nose gear touching runway before actuating abort switch			Ver. to 5.0	1.5	" "	2.0	Man		
	2.3.5D.1.3 Emergency Stop – Arrestment System	1. Engage arrestment system. 2. Steer aircraft.	1. A/C cannot be stopped prior to arrestment device. 2. Steering signals	HUD/VSD/MPD	Primary Flight & Rudders	2.0	1.5 Continuous	" " " "	2.0 2.0	Man/Machine Man/Machine	Require: Ground track steering symbology–actual and commanded	HUD/VSD May be included with items symbology. • Symbology– ground track steering required
	2.3.5D.1.4 Eject Capsule	1. Activate ejection control. See Reference: 2.1.14D.1.4 for Sequence of Events	1. Aircraft cannot be safely stopped.			2.0	1.5	" "	2.0	Man		

APPENDIX II

COMPUTER WORKLOAD EVALUATION DATA

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration Auto-TF/TA	1.0	Monitor Flight (VSD) Base	3.80
		Terrain Clearance	0
		Energy Control Director	1.00
		A/C Symbol Follow	0
		Absolute Altitude	.50
		EAS	.50
			5.80
	2.0	Monitor Terrain Avoidance (MPD-3) Base	5.8
	3.0	Monitor Navigation (HSD) Base	
		Check Points	3.80
		Turn Points	2.00
		Target	
		Present Position	1.00
		ETA	
		ETE	
		Ground Track	.75
		Compare with PP Route	.75
			8.30
	4.0	Monitor Communications	40%
	5.0	Monitor Battle Situation (MPD-4) Base	3.80
		Threat Identification	3.50
		Threat Location	.75
		Threat Priority	
		Auto Defense Actions	

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration Auto-TF/TA		Evaluate Effectiveness	
			8.05
	6.0	Monitor CITS	7.30
	7.0	Monitor Fuel Management	3.80

Summary Normal LL Pen.

PILOT WORKLOADING DATA

UNIT TIME DIST.	VISUAL		MOTOR/MANUAL			OTHER			COMMENTS:
	EXT.	INT.	L/H	R/H	FEET	COGNIT.	AUDITORY	VERBAL	
NO.	COL. 1-9	COL. 10-18	COL. 19-27	COL. 28-36	COL. 37-45	COL. 46-54	COL. 55-63	COL. 64-72	
1	3.38	30.07				16.80	12.0		
2	3.30	20.25				15.10	12.0		
3	3.28	26.32				15.00	12.00		
4	2.80	24.85				14.38	12.00		
5	3.10	27.60				15.59	12.00		
6	3.28	29.47				16.39	12.00		
7	2.72	21.03				12.68	12.00		
8	3.30	26.25				15.10	12.00		

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MINUTES) 1 2 3
1	Monitor Flight (VSD)	
	Terrain Clearance	
	Energy Control Director	
	A/C Symbol Following	
	Absolute Altitude	
	EAS	
2	Monitor Terrain Avoidance (MPD3)	
3	Monitor Navigation (HSD)	
	Check Points	
	Turn Points	
	Target	
	Present Position	
	ETA	
	ETE	
	Ground Track	
	Compare With PP Route	
4	Monitor Communications (Audio)	
5	Monitor Battle Situation (MPD4)	
	Threat Ident	
	Threat Location	
	Threat Priority	
	Auto Defense Actions	
	Evaluate Effectiveness	
6	Monitor CITS (Audio & Flashing Symbol)	
7	Monitor Fuel Mgm't (Dedicated Display)	

Figure 24. Low Level Penetration (TF/TA)

CAPTAIN WORKLOADING SUMMARY

IIPACS NORMAL LOW LEVEL PENETRATION

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	11.3	100.2	0.0	0.0	0.0	56.0	40.0	0.0	111.5	0.0	20.0	22.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
3	10.9	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0	19.9
4	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
5	10.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0	20.5
6	10.9	98.2	0.0	0.0	0.0	54.6	40.0	0.0	109.2	0.0	20.0	21.5
7	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0	17.0
8	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

IIPACS NORMAL LOW LEVEL PENETRATION

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	83.87	884.105	10.483	.837	.701
2	8	706.13	62945.392	88.267	9.392	88.212
3	8	0.00	0.000	0.000	0.000	0.000
4	8	0.00	0.000	0.000	0.000	0.000
5	8	0.00	0.000	0.000	0.000	0.000
6	8	403.47	20472.259	50.433	4.211	17.733
7	8	320.00	12799.974	40.000	.000	.000
8	8	0.00	0.000	0.000	0.000	0.000
9	8	790.00	76723.231	98.750	10.077	101.555
10	8	0.00	0.000	0.000	0.000	0.000
11	8	160.00	3199.994	20.000	.000	.000
12	8	159.74	3206.406	19.968	1.541	2.375

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration Auto TF/TA	1	Monitor Flight - VSD	5.8
Engine Failure	2	Monitor Terrain Avoidance	5.8
	3	Monitor Nav, HSD	8.3
	4	Monitor Comm	
	5	Monitor Battle Situation MPD-4	8.05
	6	Monitor CITS	7.3
	7	Monitor Fuel Management	3.8

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration Auto TF/TA	8	Observe Warning VSD	7.3
Engine Failure	9	Receive Audio Warning	2.02
	10	Observe Warning Readout MPD-5	3.8
	11	Recall Engine Display MPD-1	2.52
	12	Observe Display Parameters	2.13
	13	Decision Shutdown No. 1 Engine	.25
	14	Select Idle No. 1 LH/RS	1.92
	15	Select Off No. 1 LH/RS	1.92
	16	Select Master Off No. 1 Toggle LH	.72
	17	Observe No. 2 Parameters MPD-1	2.13
	18	Turn Off Warning	2.52

Summary - Engine Failure

PILOT WORKLOADING DATA

UNIT TIME DIST.	VISUAL		MOTOR/MANUAL			OTHER			COMMENTS:
	EXT.	INT.	L/H	R/H	FEET	COGNIT.	AUDITORY	VERBAL	
NO.	COL. 1-9	COL. 10-18	COL. 19-27	COL. 28-36	COL. 37-45	COL. 46-54	COL. 55-63	COL. 64-72	
1	2.80	24.85				14.38	12.00		
2	2.57	22.83				13.58	12.00		
3	.73	22.68	4.55	2.52		20.45	13.02		
4	1.99	17.61				11.16	12.00		
5	3.08	24.52				14.10	12.00		
6	3.53	28.27				15.90	12.00		
7	3.30	26.25				15.10	12.00		
8	3.28	26.32				15.00	12.00		

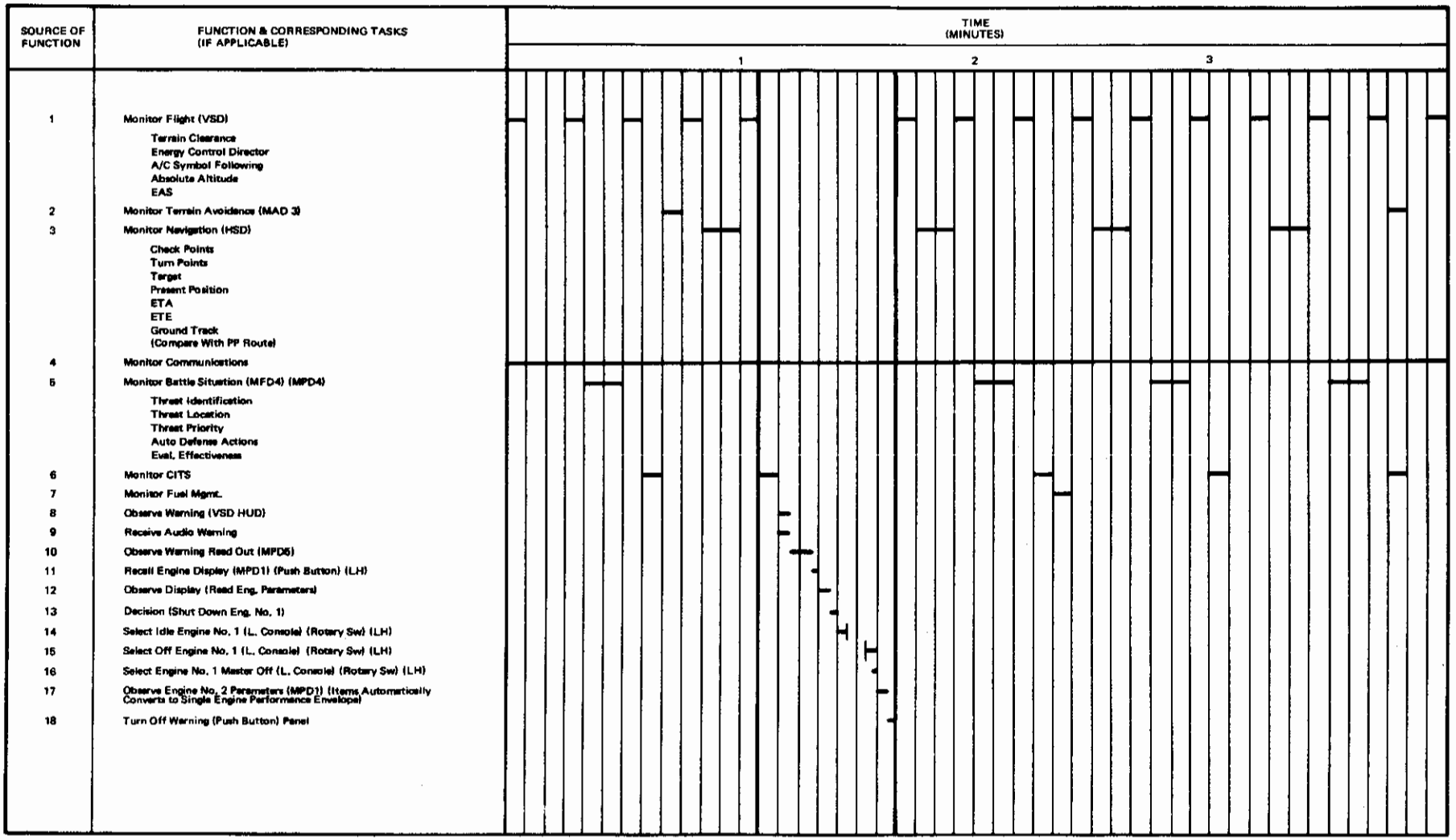


Figure 25. Low Level Penetration (TF/TA) (Engine Malfunction)

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - ENGINE MALFUNCTION

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
2	8.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0	17.9
3	2.4	75.6	15.2	8.4	0.0	68.2	43.4	0.0	78.0	7.9	21.7	25.4
4	6.6	58.7	0.0	0.0	0.0	37.2	40.0	0.0	65.3	0.0	20.0	15.0
5	10.3	81.7	0.0	0.0	0.0	47.0	40.0	0.0	92.0	0.0	20.0	18.8
6	11.8	94.2	0.0	0.0	0.0	53.0	40.0	0.0	106.0	0.0	20.0	21.0
7	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
8	10.9	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0	19.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - ENGINE MALFUNCTION

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	70.93	694.816	8.867	3.068	9.411
2	8	644.43	52727.162	80.554	10.793	116.497
3	8	15.17	230.027	1.896	5.362	28.753
4	8	8.40	70.560	1.050	2.970	8.820
5	8	0.00	0.000	0.000	0.000	0.000
6	8	398.90	20428.614	49.862	8.771	76.929
7	8	323.40	13083.534	40.425	1.202	1.445
8	8	0.00	0.000	0.000	0.000	0.000
9	8	715.37	65158.015	89.421	13.035	169.923
10	8	7.86	61.710	.982	2.777	7.714
11	8	161.70	3270.883	20.212	.601	.361
12	8	156.97	3141.110	19.622	2.951	8.710

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration TF/TA Failure	1	Monitor Flight VSD	5.8
	2	Monitor Terrain Avoidance	5.8
	3	Monitor Nav. HSD	8.3
	4	Monitor Comm	12.0
	5	Monitor Battle Situation MPD-4	8.05
	6	Monitor CITS	7.3
	7	Monitor Fuel Management	3.8
	8	Observe Warning	7.3
	9	Receive Audio Warning	1.02
	10	Observe Warning Readout MPD-5	3.8
	11	Decision -- Fly Manual	.25
	12	Turn Off Warning Signal	2.52
	13	Set Up Alternate Mode	2.52
	14	Manual Control Pitch	6.43

Summary Auto Terrain Follow Fail

PILOT WORKLOADING DATA

UNIT TIME DIST.	VISUAL		MOTOR/MANUAL			OTHER			COMMENTS:
	EXT.	INT.	L/H	R/H	FEET	COGNIT.	AUDITORY	VERBAL	
NO.	COL. 1-9	COL. 10-18	COL. 19-27	COL. 28-36	COL. 37-45	COL. 46-54	COL. 55-63	COL. 64-72	
1	2.80	21.03				12.68	12.00		
2	2.72	21.03				12.68	12.00		
3	.73	19.56	5.04	6.43		17.61	14.02		
4	4.11	29.67		19.29		24.30	12.00		
5	4.09	25.92		25.72		25.06	12.00		
6	3.38	26.25		25.72		25.34	12.00		
7	3.66	25.92		25.72		25.06	12.00		
8	4.11	29.67		25.72		26.86	12.00		

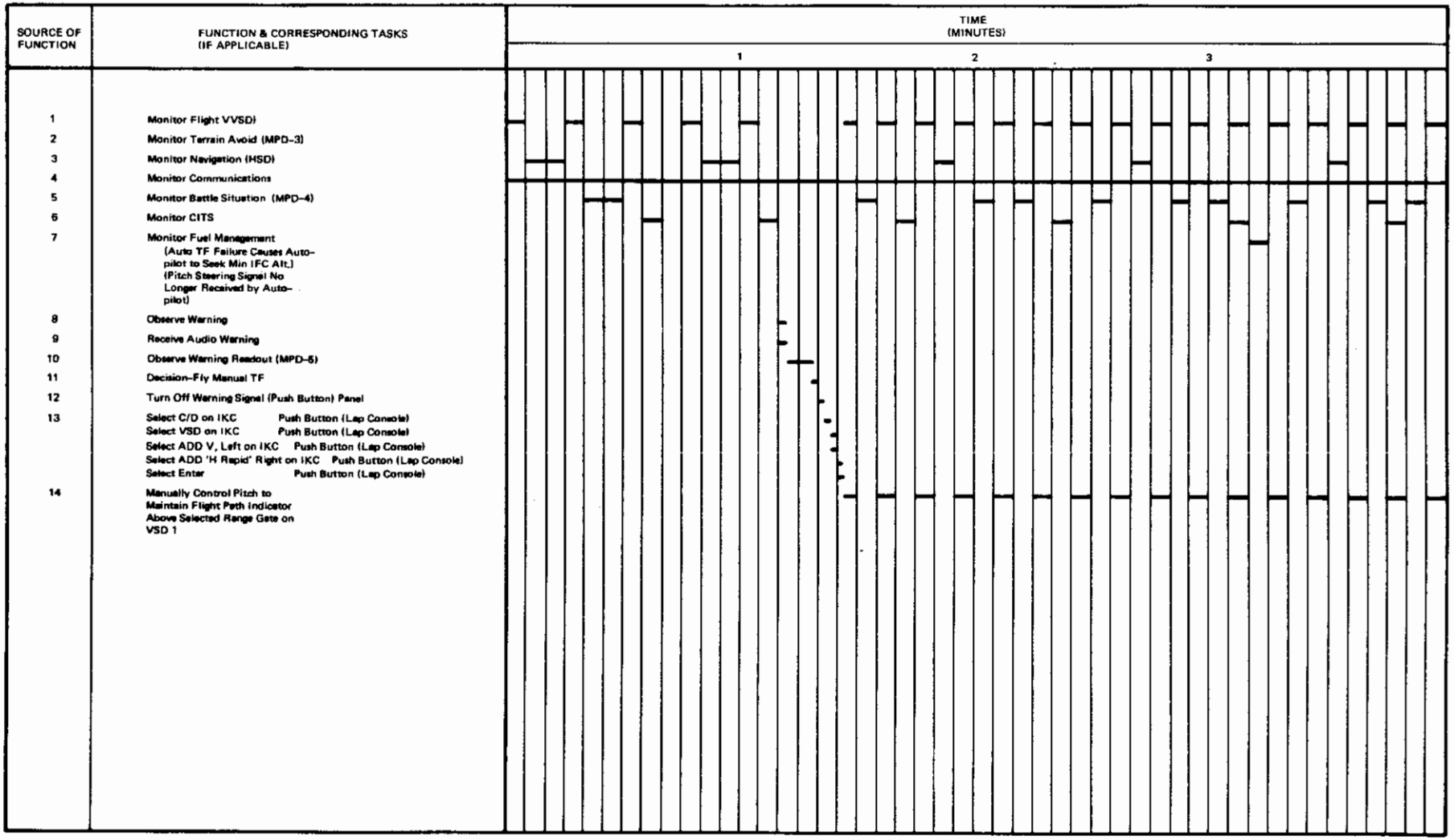


Figure 26. Low Level Penetration (TF/TA) (Auto Terrain Following Failure)

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
2	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0	17.0
3	2.4	65.2	16.8	21.4	0.0	58.7	46.7	0.0	67.6	12.7	23.4	25.7
4	13.7	98.9	0.0	64.3	0.0	81.0	40.0	0.0	112.6	21.4	20.0	36.9
5	13.6	86.4	0.0	85.7	0.0	83.5	40.0	0.0	100.0	28.6	20.0	39.9
6	11.3	87.5	0.0	85.7	0.0	84.5	40.0	0.0	98.8	28.6	20.0	39.9
7	12.2	86.4	0.0	85.7	0.0	83.5	40.0	0.0	98.6	28.6	20.0	39.8
8	13.7	98.9	0.0	85.7	0.0	89.5	40.0	0.0	112.6	28.6	20.0	41.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	85.33	1012.260	10.667	3.818	14.577
2	8	663.50	56227.538	82.937	13.086	171.231
3	8	16.80	282.239	2.100	5.940	35.280
4	8	428.67	33994.628	53.583	39.687	1575.041
5	8	0.00	0.000	0.000	0.000	0.000
6	8	565.30	42686.018	70.662	19.787	391.512
7	8	326.73	13383.978	40.842	2.381	5.667
8	8	0.00	0.000	0.000	0.000	0.000
9	8	748.83	71992.142	93.604	16.468	271.195
10	8	148.49	3888.558	18.561	12.719	161.778
11	8	163.37	3345.994	20.421	1.190	1.417
12	8	258.09	9124.678	32.261	10.679	114.040

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Nav Satellite Failure	1	Monitor Flight VSD	5.8
	2	Monitor Terrain Avoidance	5.8
	3	Monitor Nav. HSD	8.3
	4	Monitor Comm	12.0
	5	Monitor Battle Situation MPD-4	8.05
	6	Monitor CITS	7.5
	7	Monitor Fuel Management	3.8
	8	Observe Predicted Nav Error (MPD)	4.55
	9	Search Map/Radar for CP 15	6.55
	10	Select Nav System Situation	2.69
	11	Observe X-hair/Check Point Release	4.30
	12	Select Freez	1.44
	13	Enable Trackball	1.44
	14	Align Cursor With Trackball	7.50
	15	Select Update	1.44
	16	Observe A/C Course Change	7.55
	17	Disable Track Ball	1.44

Summary Nav Satellite Fail

PILOT WORKLOADING DATA

UNIT TIME DIST.	VISUAL		MOTOR/MANUAL			OTHER			COMMENTS:
	EXT.	INT.	L/H	R/H	FEET	COGNIT.	AUDITORY	VERBAL	
NO.	COL 1-9	COL. 10-18	COL. 19-27	COL. 28-36	COL. 37-45	COL. 46-54	COL. 55-63	COL. 64-72	
1	2.80	21.03				12.68	12.00		
2	3.30	26.26				15.10	12.00		
3	.76	29.69		15.95		19.35	12.00		
4	2.80	21.03				12.68	12.00		
5	.76	29.69		15.95		19.35	12.00		
6	2.80	21.03				12.68	12.00		
7	2.57	22.83				13.58	12.00		
8	3.51	20.70				12.40	12.00		

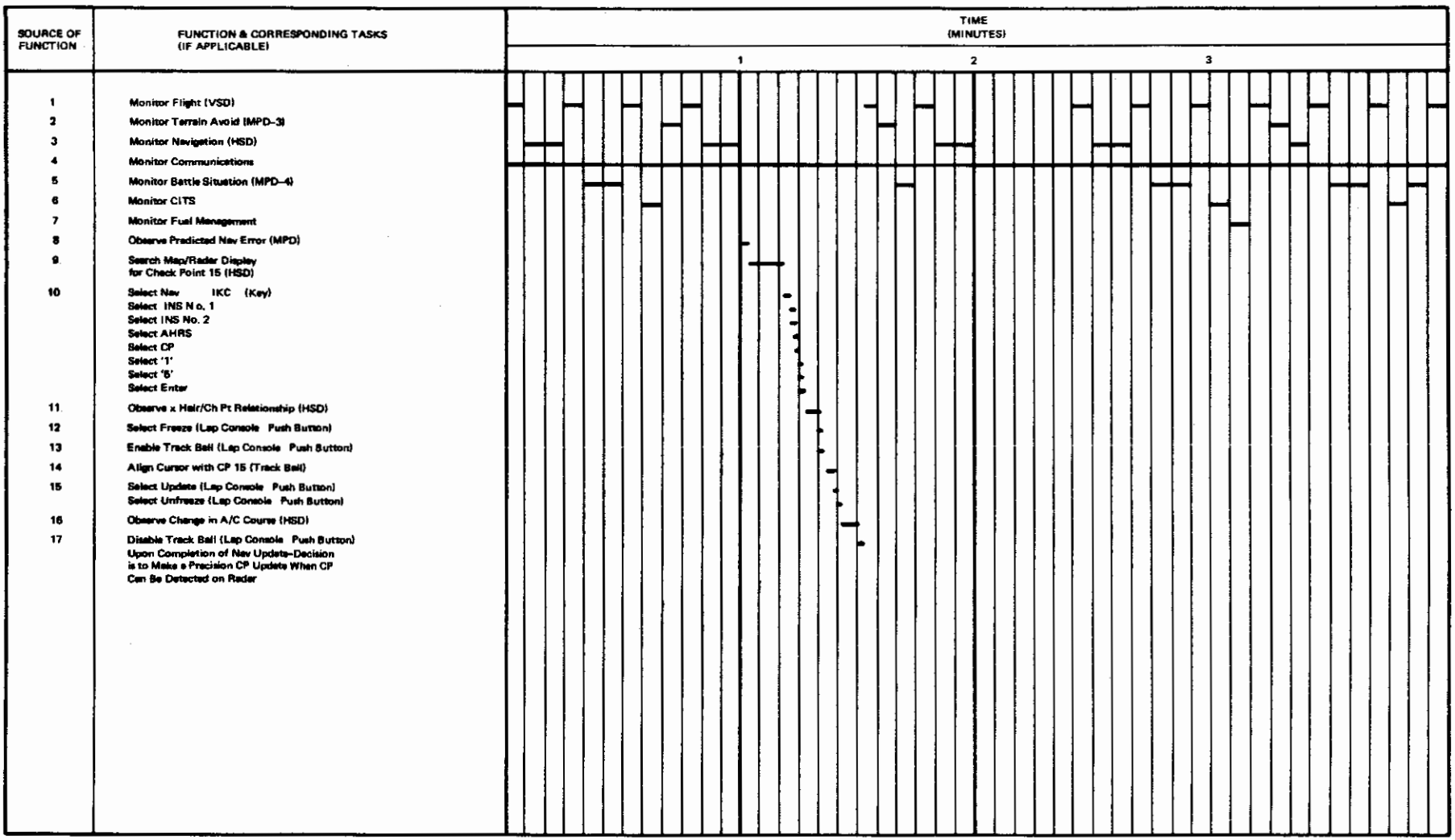


Figure 27. Low Level Penetration (TF/TA) (Navigation Satellite Failure)

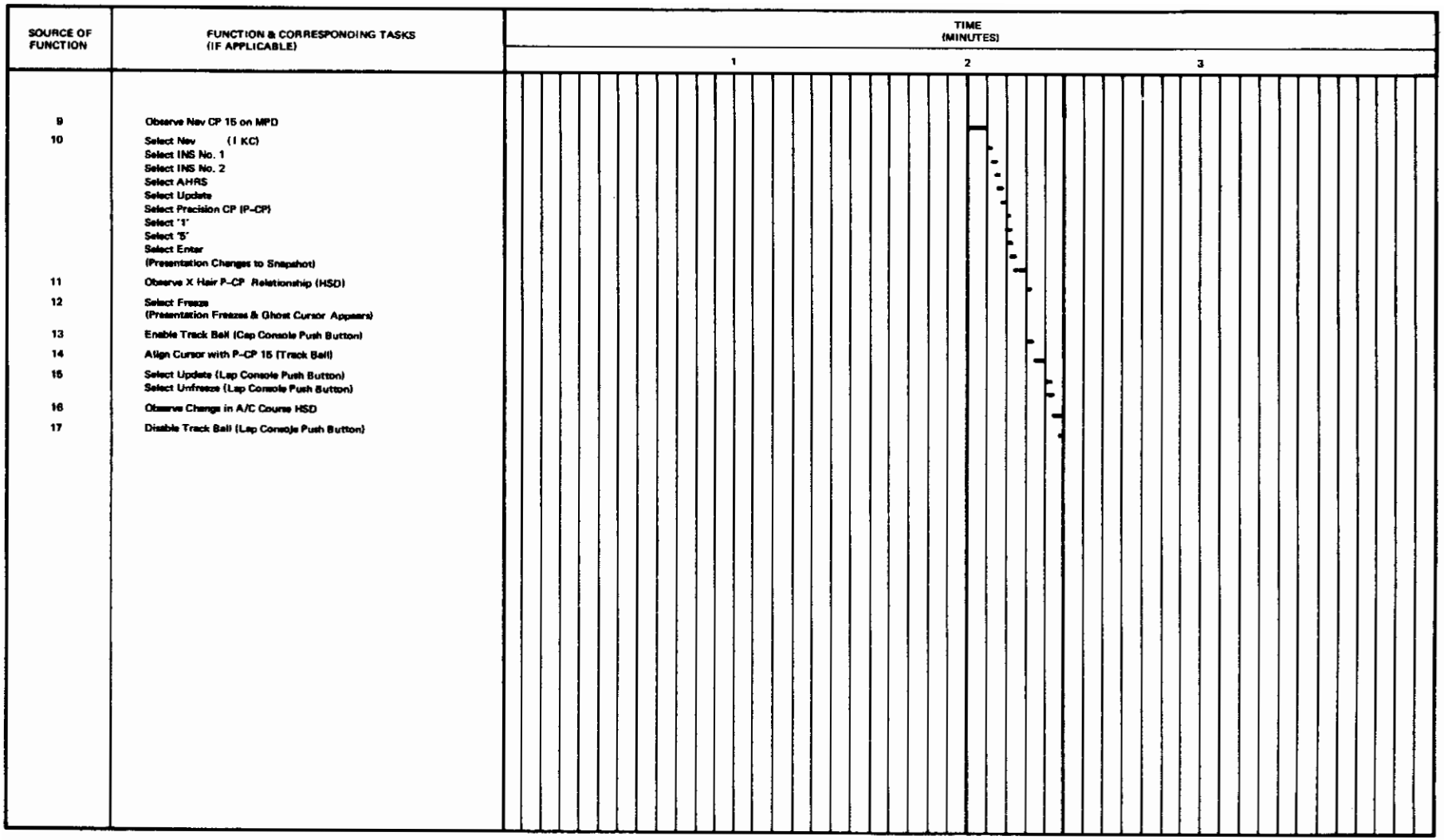


Figure 27. Low Level Penetration (TF/TA) (Navigation Satellite Failure) (Continued)

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
3	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0	31.4
4	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
5	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0	31.4
6	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
7	8.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0	17.5
8	11.7	69.0	0.0	0.0	0.0	41.3	40.0	0.0	80.7	0.0	20.0	16.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	64.33	605.445	8.042	3.548	12.586
2	8	640.83	52539.187	80.104	13.125	172.267
3	8	0.00	0.000	0.000	0.000	0.000
4	8	106.33	5653.378	13.292	24.611	605.719
5	8	0.00	0.000	0.000	0.000	0.000
6	8	392.73	19970.833	49.092	9.935	98.705
7	8	320.00	12799.974	40.000	.000	.000
8	8	0.00	0.000	0.000	0.000	0.000
9	8	705.17	62916.522	88.146	10.414	108.449
10	8	35.44	628.153	4.431	8.204	67.302
11	8	160.00	3199.994	20.000	.000	.000
12	8	168.61	3845.018	21.076	6.452	41.633

REPRESENTATIVE MISSION REQUIREMENTS

MISSION PHASE	TASK	MISSION TASKS	TASK TIME BUDGET
LIST	SEQUENCE	LIST	(SECONDS)
Low Level Penetration Auto TF/TA	1	Monitor Flight VSD	5.8
Electrical Distribution Failure	2	Monitor Terrain Avoidance	5.8
	3	Monitor Nav. HSD	8.3
	4	Monitor Comm	12.0
	5	Monitor Battle Situation MPD-4	8.05
	6	Monitor CITS	7.30
	7	Monitor Fuel Management	3.8
	8	Observe Warning (VSD)	7.3
	9	Receive Audio Warning	1.02
	10	Observe Warning Readout MPD-5	3.8
	11	Select Elect Parameters on Keyboard	2.52
	12	Observe Parameters MPD-1	3.8
	13	Reset RT VSCF-Off	.71
	14	Right Gen. Off Then On	.71
	15	Reset RT VSCF-On	.71
	16	Observe Readout MPD-1	3.13
	17	Disconnect RT Gen.	.71
	18	Select Avionics Buss - Off	.71
	19	Warning Signal Off	2.52
	20	Select Elect System Test on Keyboard	2.52
	21	Observe Malfunction MPD-5	3.13
	22	Select Avionics Buss - On	.71
	23	Select Pen Aids on Keyboard	2.52
	24	Select C&I Data on Keyboard	2.52

Elect Distirbution Fail

PILOT WORKLOADING DATA

UNIT TIME DIST.	VISUAL		MOTOR/MANUAL			OTHER			COMMENTS:
	EXT.	INT.	L/H	R/H	FEET	COGNIT.	AUDITORY	VERBAL	
NO.	COL. 1-9	COL. 10-18	COL. 19-27	COL. 28-36	COL. 37-45	COL. 46-54	COL. 55-63	COL. 64-72	
1	2.80	24.85				14.38	12.00		
2	3.30	29.34				16.49	12.00		
3	.71	27.39	3.05	7.56		24.26	14.02		
4	.81	15.77	.71	5.04		14.56	12.00		
5	3.30	29.40				16.49	12.00		
6	3.85	25.65				14.69	12.00		
7	2.80	24.85				14.38	12.00		
8	3.10	27.60				15.59	12.00		

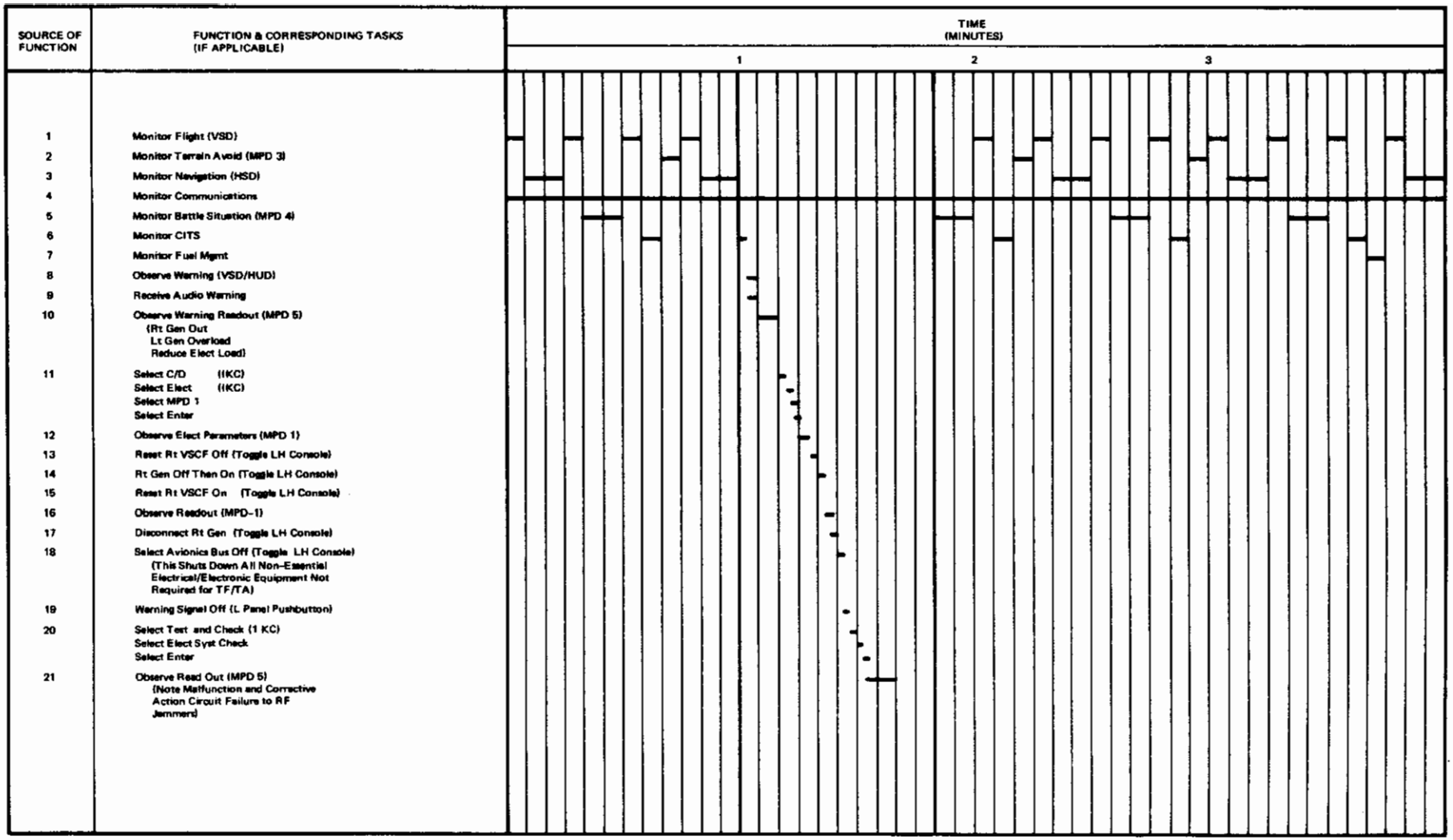


Figure 28. Low Level Penetration (TF/TA) (Elect. Distribution Failure)

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MINUTES) 1 2 3
ZZ	Select Avionics Bus On (Toggle L Console) (Systems Previously Shut Down Must Be Selectively Turned On)	
23	Select Pen Aids (1 KC) Select RHAW Select IR Warn Select Enter	
	Other Systems Turned On As Required	
	Systems Left In the Off Position Include: TACAN Landing Aids Satellite Nav AHRS Collision Avoidance RF Jammers HF Comm VHF Comm UHF Comm BDA L^{3}TV FLIR Laser	
24	Select Cat IKC Select Secure Select Voice Select Data Link Select Enter	

Figure 28. Low Level Penetration (TF/TA) (Elect. Distribution Failure) (Continued)

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
2	11.0	97.8	0.0	0.0	0.0	55.0	40.0	0.0	108.8	0.0	20.0	21.6
3	2.4	91.3	10.2	25.2	0.0	80.9	46.7	0.0	93.7	11.8	23.4	31.1
4	2.7	52.6	2.4	16.8	0.0	48.5	40.0	0.0	55.3	6.4	20.0	19.2
5	11.0	98.0	0.0	0.0	0.0	55.0	40.0	0.0	109.0	0.0	20.0	21.6
6	12.8	85.5	0.0	0.0	0.0	49.0	40.0	0.0	98.3	0.0	20.0	19.7
7	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
8	13.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0	20.5

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	68.90	700.584	8.612	3.913	15.312
2	8	682.83	59764.637	85.354	14.551	211.726
3	8	12.53	108.962	1.567	3.572	12.761
4	8	42.00	917.278	5.250	9.977	99.540
5	8	0.00	0.000	0.000	0.000	0.000
6	8	436.13	24631.000	54.517	11.049	122.073
7	8	326.73	13303.978	40.842	2.381	5.667
8	8	0.00	0.000	0.000	0.000	0.000
9	8	751.73	72677.088	93.967	17.069	291.336
10	8	18.18	179.795	2.272	4.448	19.785
11	8	163.37	3345.994	20.421	1.190	1.417
12	8	171.65	3796.476	21.456	4.027	16.217

APPENDIX III

COMPUTER WORKLOAD ANALYSIS SUMMARY

CAPTAIN WORKLOADING SUMMARY

IIPACS NORMAL LOW LEVEL PENETRATION

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	11.3	100.2	0.0	0.0	0.0	56.0	40.0	0.0	111.5	0.0	20.0	22.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
3	10.9	87.7	0.0	0.0	0.0	50.9	40.0	0.0	98.7	0.0	20.0	19.9
4	9.3	82.2	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
5	10.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0	20.5
6	10.9	98.2	0.0	0.0	0.0	54.6	40.0	0.0	109.2	0.0	20.0	21.5
7	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0	17.0
8	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

IIPACS NORMAL LOW LEVEL PENETRATION

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	83.87	884.105	10.483	.837	.701
2	8	706.13	62945.392	88.267	9.392	88.212
3	8	0.00	0.000	0.000	0.000	0.000
4	8	0.00	0.000	0.000	0.000	0.000
5	8	0.00	0.000	0.000	0.000	0.000
6	8	403.47	20472.259	50.433	4.211	17.733
7	8	320.00	12799.974	40.000	.000	.000
8	8	0.00	0.000	0.000	0.000	0.000
9	8	790.00	76723.231	98.750	10.077	101.555
10	8	0.00	0.000	0.000	0.000	0.000
11	8	160.00	3199.994	20.000	.000	.000
12	8	159.74	3206.406	19.968	1.541	2.375

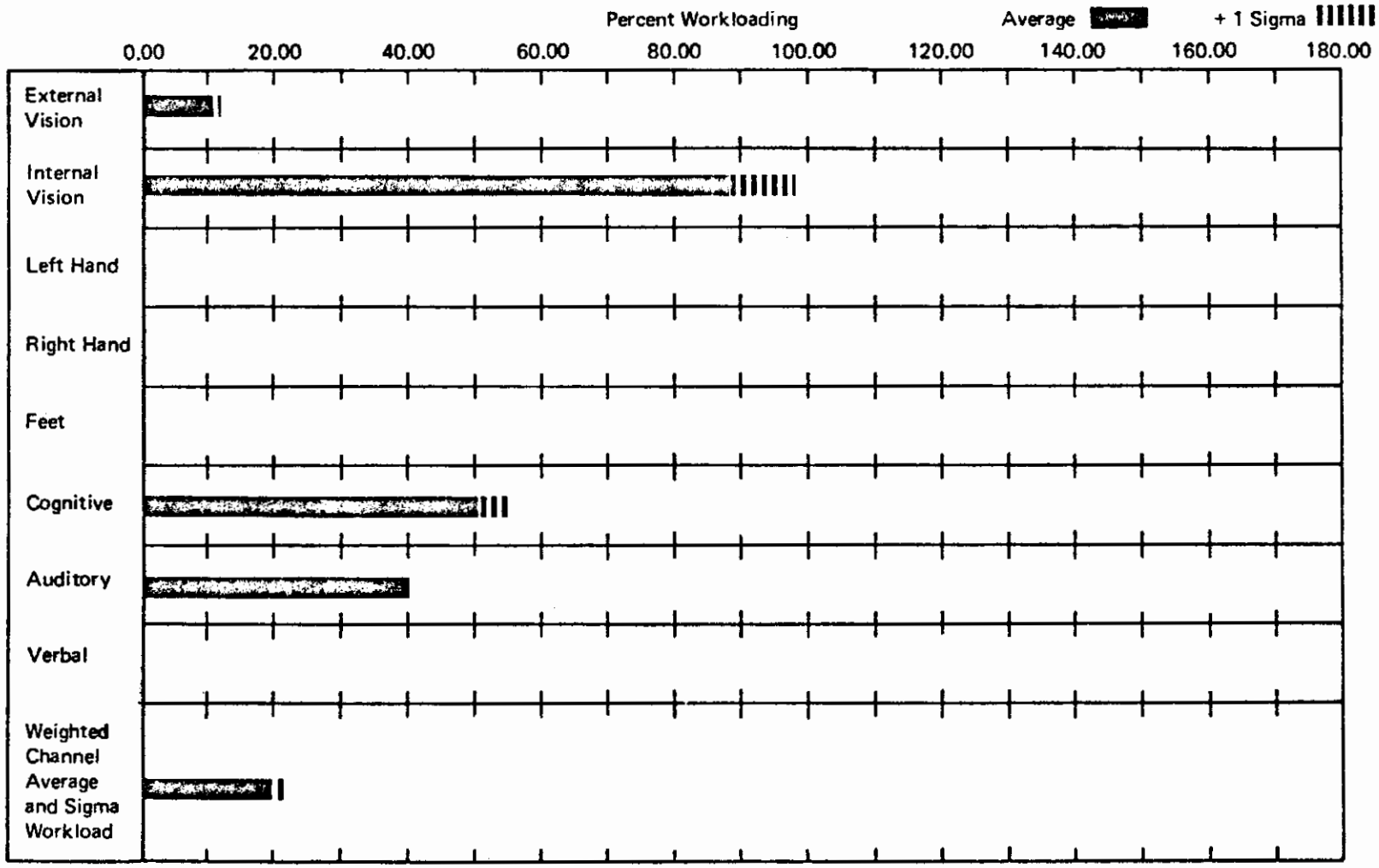


Figure 29. IIPACS Normal Low Level Penetration

Captain
Crew Member

Oct 29, 1970
Date

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - ENGINE MALFUNCTION

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
2	8.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0	17.9
3	2.4	75.6	15.2	8.4	0.0	68.2	43.4	0.0	78.0	7.9	21.7	25.4
4	6.6	58.7	0.0	0.0	0.0	37.2	40.0	0.0	65.3	0.0	20.0	15.0
5	10.3	81.7	0.0	0.0	0.0	47.0	40.0	0.0	92.0	0.0	20.0	18.8
6	11.8	94.2	0.0	0.0	0.0	53.0	40.0	0.0	106.0	0.0	20.0	21.0
7	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
8	10.9	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0	19.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - ENGINE MALFUNCTION

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	70.93	694.816	8.867	3.068	9.411
2	8	644.43	52727.162	80.554	10.793	116.497
3	8	15.17	230.027	1.896	5.362	28.753
4	8	8.40	70.560	1.050	2.970	8.820
5	8	0.00	0.000	0.000	0.000	0.000
6	8	398.90	20428.614	49.862	8.771	76.929
7	8	323.40	13083.534	40.425	1.202	1.445
8	8	0.00	0.000	0.000	0.000	0.000
9	8	715.37	65158.015	89.421	13.035	169.923
10	8	7.86	61.710	.982	2.777	7.714
11	8	161.70	3270.883	20.212	.601	.361
12	8	156.97	3141.110	19.622	2.951	8.710

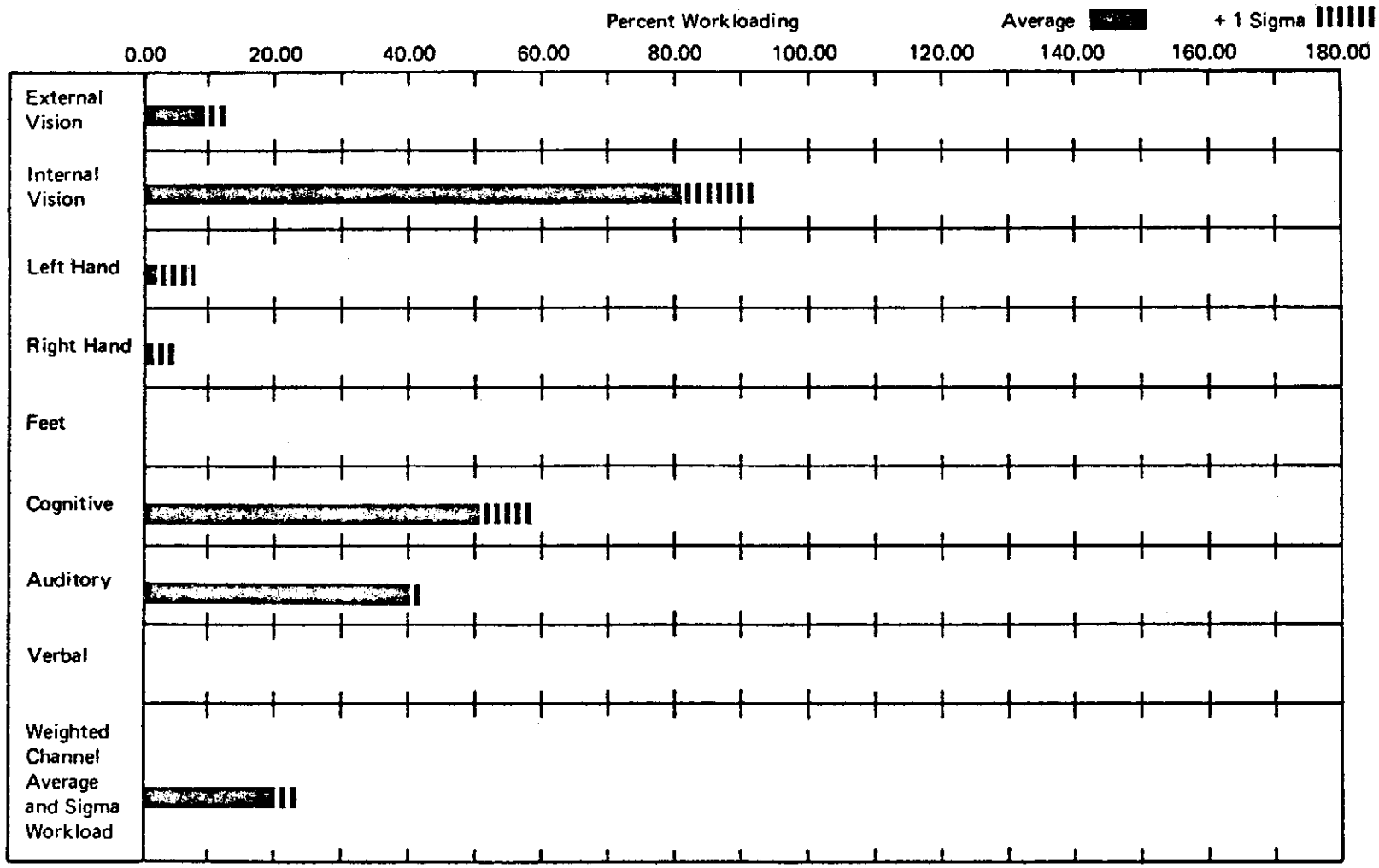


Figure 30. IIPACS Low Level Penetration–Engine Malfunction

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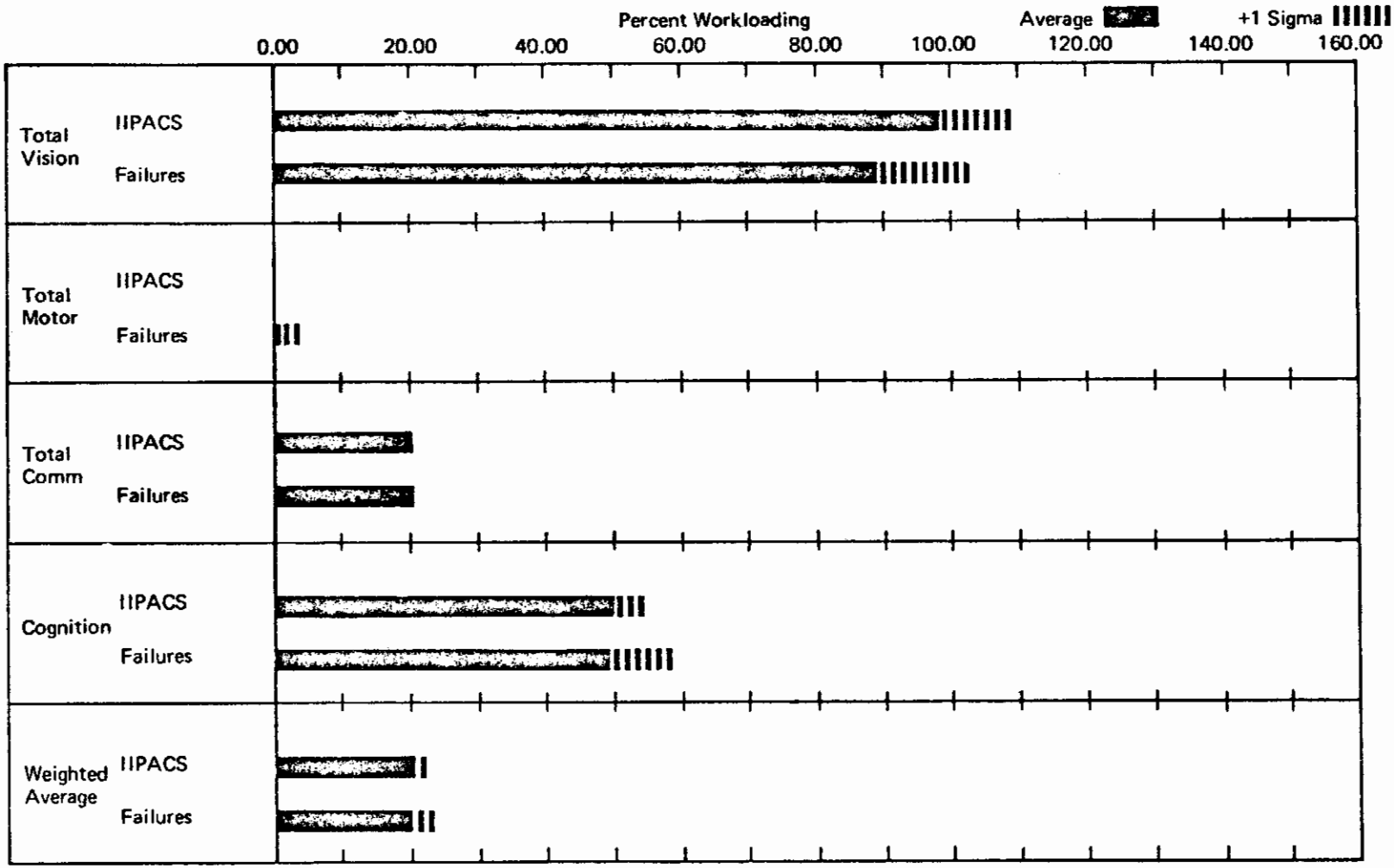

Figure 31. Normal Low Level Penetration–Engine Malfunction

Captain
Crew Member

Oct 29,1970
Date

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
2	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0	17.0
3	2.4	65.2	16.8	21.4	0.0	58.7	46.7	0.0	67.6	12.7	23.4	25.7
4	13.7	98.9	0.0	84.3	0.0	81.0	40.0	0.0	112.6	21.4	20.0	36.9
5	13.6	86.4	0.0	85.7	0.0	83.5	40.0	0.0	100.0	28.6	20.0	39.9
6	11.3	87.5	0.0	85.7	0.0	84.5	40.0	0.0	98.8	28.6	20.0	39.9
7	12.2	86.4	0.0	85.7	0.0	83.5	40.0	0.0	98.6	28.6	20.0	39.8
8	13.7	98.9	0.0	85.7	0.0	89.5	40.0	0.0	112.6	28.6	20.0	41.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	85.33	1012.260	10.667	3.818	14.577
2	8	663.50	56227.538	82.937	13.086	171.231
3	8	16.80	282.239	2.100	5.940	35.280
4	8	428.67	33994.628	53.583	39.687	1575.041
5	8	0.00	0.000	0.000	0.000	0.000
6	8	565.30	42686.018	70.662	19.787	391.512
7	8	326.73	13303.978	40.842	2.381	5.667
8	8	0.00	0.000	0.000	0.000	0.000
9	8	748.83	71992.142	93.604	16.468	271.195
10	8	148.49	3888.558	18.561	12.719	161.778
11	8	163.37	3345.994	20.421	1.190	1.417
12	8	258.09	9124.678	32.261	10.679	114.040

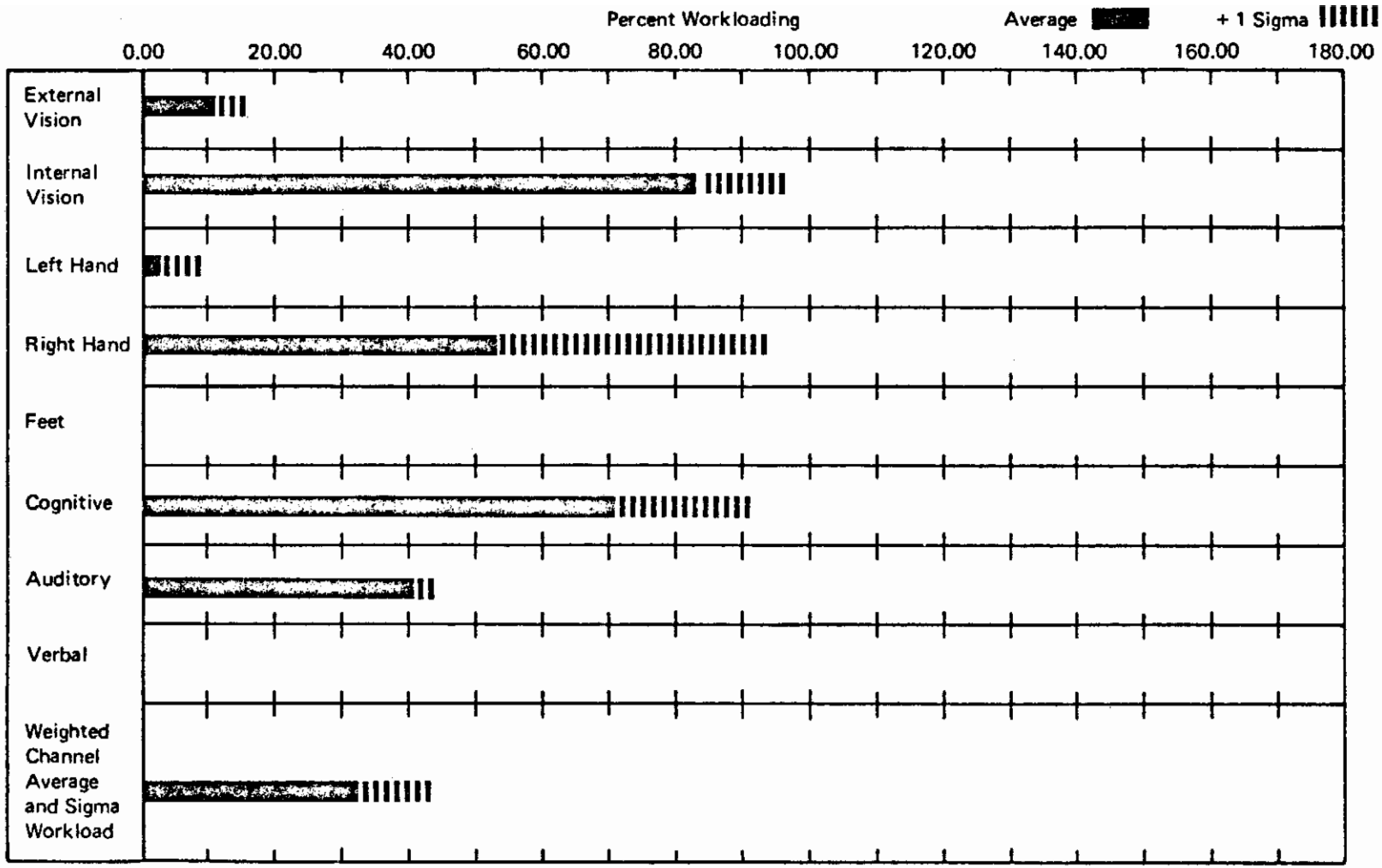

Figure 32. IIPACS Low Level Penetration– Auto Terrain Following Failure

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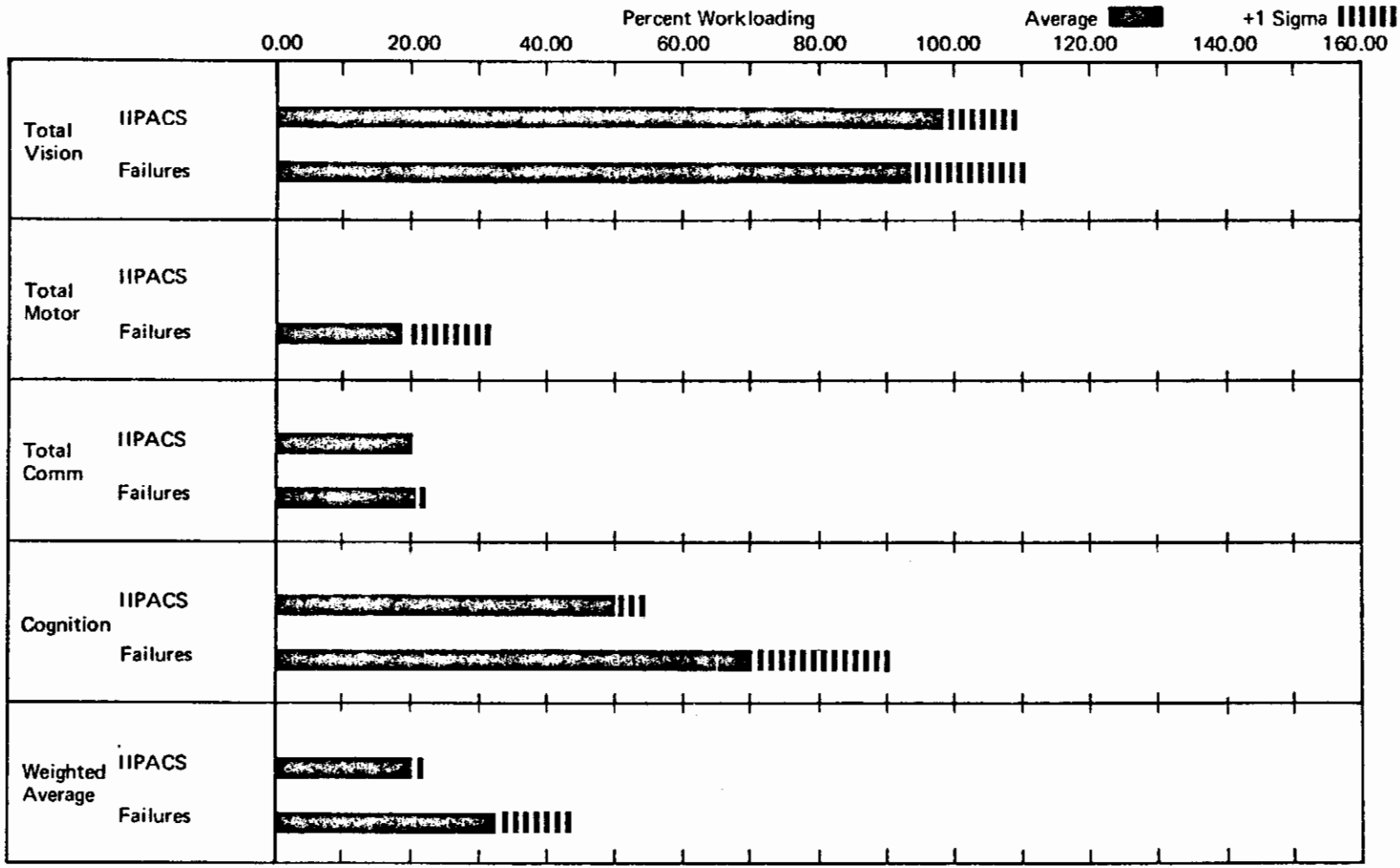

Figure 33. Normal Low Level Penetration- Auto Terrain Following Failure

Captain
Crew Member

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Date

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0	19.9
3	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0	31.4
4	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
5	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0	31.4
6	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
7	8.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0	17.9
8	11.7	69.0	0.0	0.0	0.0	41.3	40.0	0.0	80.7	0.0	20.0	16.9

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	64.33	605.445	8.042	3.548	12.586
2	8	640.83	52539.187	80.104	13.125	172.267
3	8	0.00	0.000	0.000	0.000	0.000
4	8	106.33	5653.378	13.292	24.611	605.719
5	8	0.00	0.000	0.000	0.000	0.000
6	8	392.73	19970.833	49.092	9.935	98.705
7	8	320.00	12799.974	40.000	.000	.000
8	8	0.00	0.000	0.000	0.000	0.000
9	8	705.17	62916.522	88.146	10.414	108.449
10	8	35.44	628.153	4.431	8.204	67.302
11	8	160.00	3199.994	20.000	.000	.000
12	8	168.61	3845.018	21.076	6.452	41.633

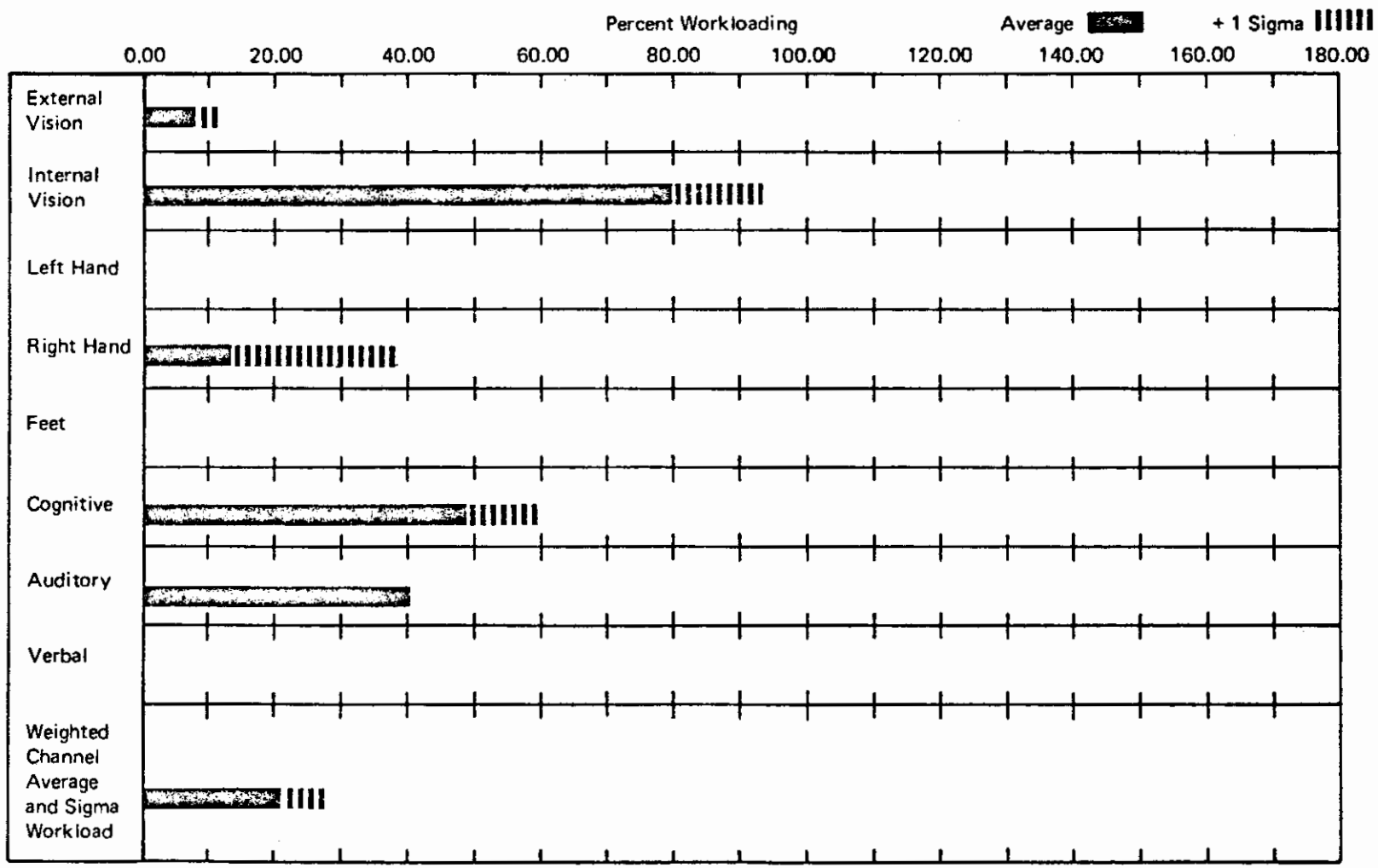

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Figure 34. IIPACS Low Level Penetration- Nav. Sat. Failure

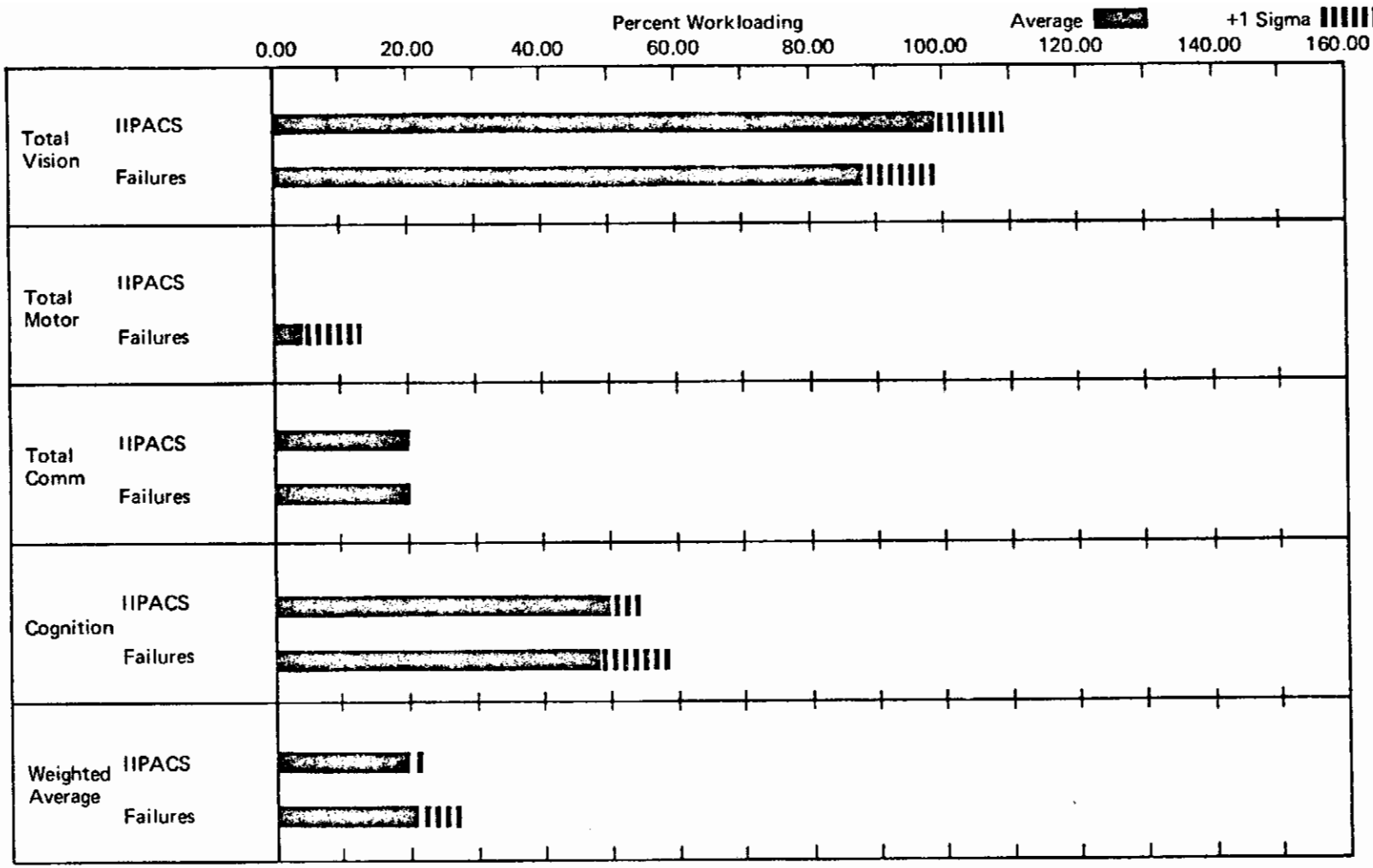

Figure 35. Normal Low Level Penetration- Nav. Sat. Failure

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Date

CAPTAIN WORKLOADING SUMMARY

FAILURES LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

NO. (I)	(1) EXT VIS	(2) INT VIS	(3) LFT HAND	(4) RT HAND	(5) FEET	(6) COGN	(7) AUDIT	(8) VERB	(9) TOTAL VIS	(10) TOTAL MOTOR	(11) TOTAL COMM	(12) AVE
1	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
2	11.0	97.8	0.0	0.0	0.0	55.0	40.0	0.0	108.8	0.0	20.0	21.6
3	2.4	91.3	10.2	25.2	0.0	80.9	46.7	0.0	93.7	11.8	23.4	31.1
4	2.7	52.6	2.4	16.8	0.0	48.5	40.0	0.0	55.3	6.4	20.0	19.2
5	11.0	98.0	0.0	0.0	0.0	55.0	40.0	0.0	109.0	0.0	20.0	21.6
6	12.8	85.5	0.0	0.0	0.0	49.0	40.0	0.0	98.3	0.0	20.0	19.7
7	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
8	10.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0	20.5

CAPTAIN WORKLOADING SUMMARY

AVERAGE AND STANDARD DEVIATION

WORKLOADING PER UNIT TIME

FAILURES LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	68.90	700.584	8.612	3.913	15.312
2	8	682.03	59764.637	85.354	14.551	211.726
3	8	12.53	108.962	1.567	3.572	12.761
4	8	42.00	917.278	5.250	9.977	99.540
5	8	0.00	0.000	0.000	0.000	0.000
6	8	436.13	24631.000	54.517	11.049	122.073
7	8	326.73	13383.978	40.842	2.391	5.667
8	8	0.00	0.000	0.000	0.000	0.000
9	8	751.73	72677.088	93.967	17.069	291.336
10	8	18.18	179.795	2.272	4.448	19.785
11	8	163.37	3345.994	20.421	1.190	1.417
12	8	171.65	3796.476	21.456	4.027	16.217

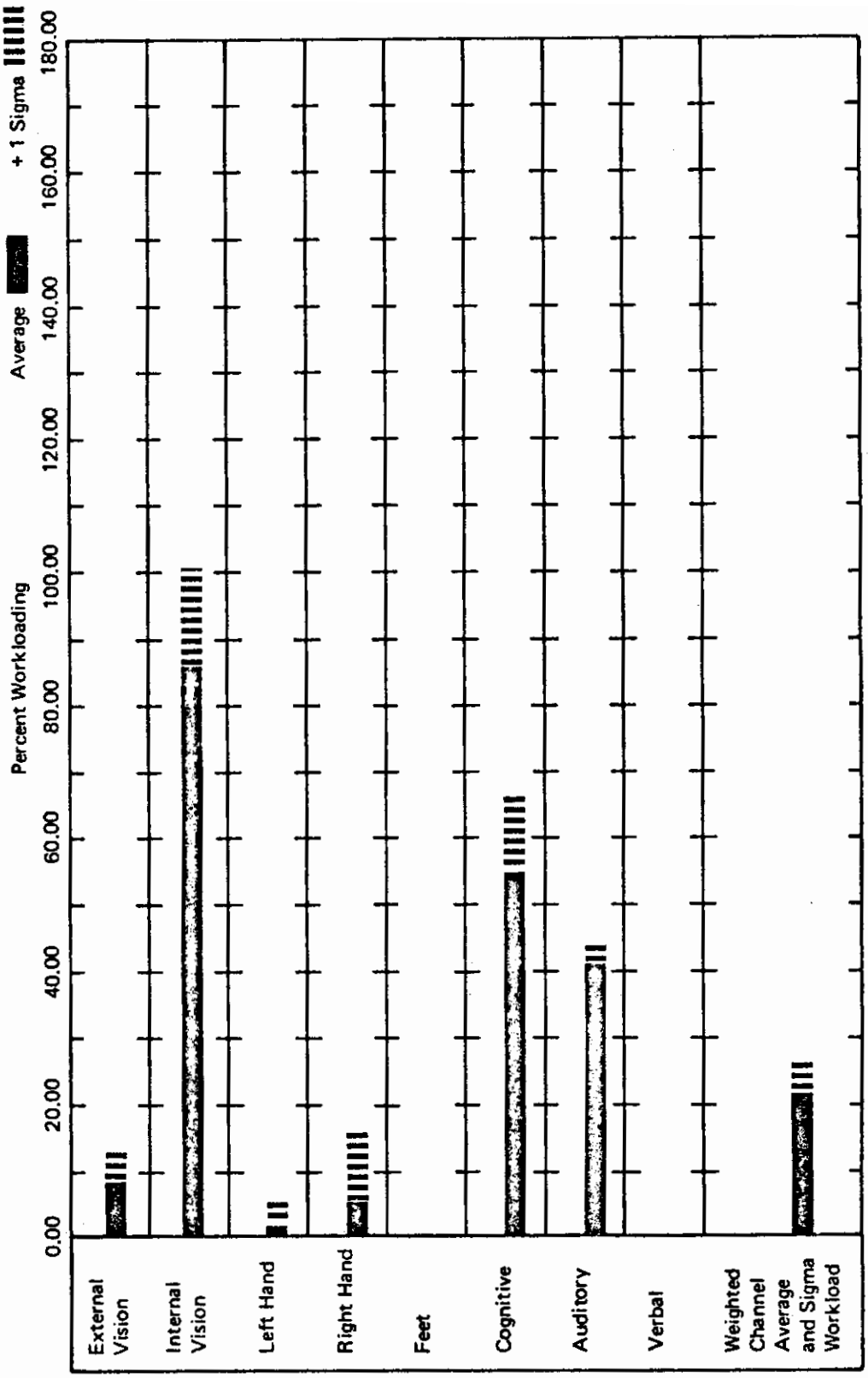

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Figure 36. IIPACS Low Level Penetration– Elect. Dist. Failure

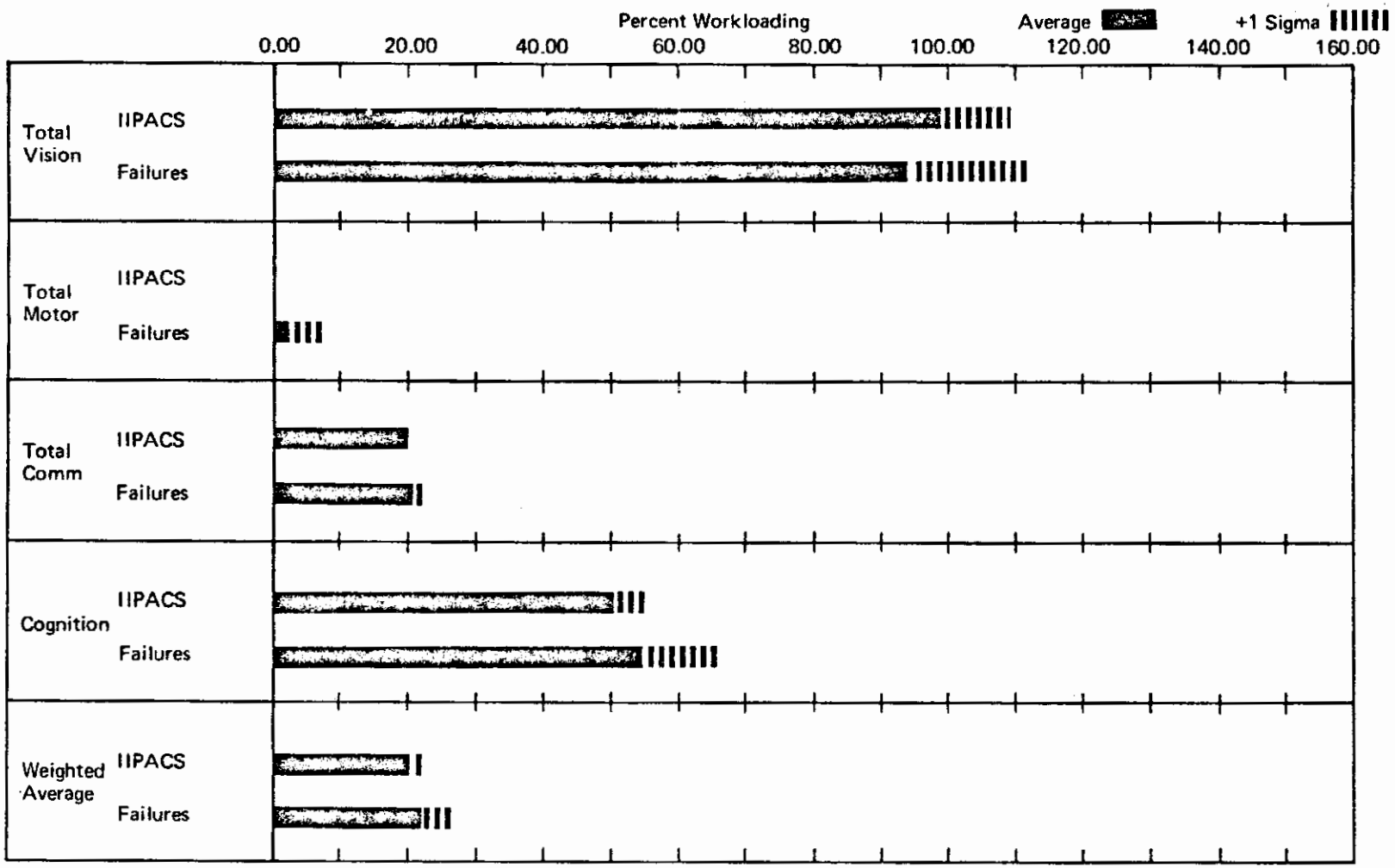

Figure 37. Normal Low Level Penetration – Elect. Dist. Failure

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Oct 29,1970
Date

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13. ABSTRACT

The "Integrated Information Presentation and Control System Study" (IIPACS-1), Volumes I and II, Air Force Flight Dynamics Laboratory report AFFDL-TR-70-79, describes three cockpit concepts developed to significantly reduce workload for the tactical fighter pilots of the 1980's.

The wraparound cockpit of the IIPACS-1 was selected as the baseline configuration for systematic degraded mode analyses. The cockpit concept was evaluated subjectively and by means of a computerized workload analysis. The results of the analyses and evaluations, conducted to determine the control and display requirements for contingency operations, are reported in this document, AFFDL-TR-70-79, Volume III.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Automatic Flight Management						
Close Air Support Mission						
Computer Control						
Computer Generated Displays						
Controls						
Crew Station						
Displays						
Electronic Display						
Energy Management						
Functional Flow Diagram						
Integrated Avionics						
Integration						
Sidearm Controllers						
System Analysis						
Weapon Delivery						
Workload						

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