

CONTROL - DISPLAY INTEGRATION PROGRAM

AFFDL-TR-70-79

Volume III

INTEGRATED INFORMATION PRESENTATION AND CONTROL SYSTEM STUDY

Volume III, Degraded Mode Analysis

AD 740435

S. J. PREMSELAAR

J. G. HATCHER

R. L. RICHARDSON

R. L. KINNAMEN

W. D. SMITH

THE BOEING COMPANY

MILITARY AIRPLANE SYSTEMS DIVISION

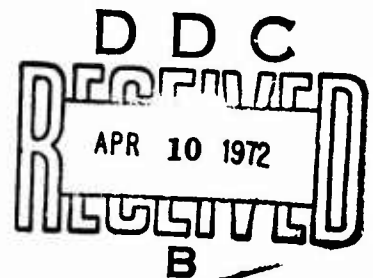
TECHNICAL REPORT AFFDL-TR-70-79, VOLUME III

JUNE 1971

Distribution of this document is Unlimited.

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO



162

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited



NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

ACCESSION NO.	
CFSTI	WRITE SECTION ☒
DDC	SUFF SECTION ☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
DIST.	AVAIL. and/or SPECIAL
A	

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

AIR FORCE: 27-12-71/300

Unclassified

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) The Boeing Company Military Airplane Systems Division Seattle, Washington 98124		2a. REPORT SECURITY CLASSIFICATION Unclassified	
		2b. GROUP N/A	
3. REPORT TITLE Integrated Information Presentation and Control System Study Volume III: Degraded Mode Analysis			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final Draft			
5. AUTHOR(S) (First name, middle initial, last name) S. J. Prenselaar, J. C. Hatcher, R. L. Richardson, R. L. Kinnaman, and W. D. Smith			
6. REPORT DATE June 1971		7a. TOTAL NO. OF PAGES 151	7b. NO. OF REFS 2
8a. CONTRACT OR GRANT NO. F33615-70-C-1832		8b. ORIGINATOR'S REPORT NUMBER(S)	
b. PROJECT NO.			
c.		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		AFFDL-TR-70-79, Volume III	
10. DISTRIBUTION STATEMENT			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Air Force Flight Vehicles Lab. Wright-Patterson AFB, Ohio 45433	
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.			

DD FORM 1 NOV 65 1473

Unclassified

Security Classification

Unclassified

Security Classification

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						

AFFDL-TR-70-79

Volume III

**INTEGRATED INFORMATION PRESENTATION
AND CONTROL SYSTEM STUDY**

Volume III, Degraded Mode Analysis

S. J. PREMSELAAR

J. G. HATCHER

R. L. RICHARDSON

R. L. KINNAMEN

W. D. SMITH

*THE BOEING COMPANY
MILITARY AIRPLANE SYSTEMS DIVISION*

TECHNICAL REPORT AFFDL-TR-70-79, VOLUME III

JUNE 1971

Distribution of this document is Unlimited.

**AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

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.

Acknowledgement for significant contributions goes to: S. J. Premelaar, Principal Investigator; J. G. Hatcher, R. L. Richardson, R. L. Kinnaman, degraded mode analysis; W. D. Smith, workload analysis; and Capt. N. A. Kopchick, Technical Monitor for the Air Force Flight Dynamics Laboratory.

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.

RICHARD D. ALBERTS
Plans Office
Air Force Avionics Lab.



JOHN H. KEARNS, III
Acting Chief
Flight Deck Development Branch
Flight Control Division
Air Force Flight Dynamics Lab.

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.

TABLE OF CONTENTS

		Page
I	INTRODUCTION	1
II	STUDY METHOD	2
	1. Phase I - Degraded Mode Survey	2
	2. Phase II - Degraded Mode Analyses and Design	4
	3. Phase III - Mockup and Evaluation	5
	4. Computerized Workload Evaluation	6
III	CONCLUSIONS	12
APPENDICES		
I	SELECTED FAILURES	14
II	COMPUTER WORKLOAD EVALUATION DATA	114
III	COMPUTER WORKLOAD ANALYSIS SUMMARY	136

LIST OF ILLUSTRATIONS

<u>Figure No.</u>		<u>Page</u>
1	IIPACS-2 Program Flow Chart	3
2	Crew-Workload Evaluation Method	7
3	Workload Summary	12
4	APU Failure	42
5	NLG Steering Failure	44
6	Engine Fire	46
7	Engine Failure	51
8	High-Lift Devices Failure	58
9	Landing Gear Failure	61
10	Environmental Control System Failure	66
11	TACAN Station Keeping Function Fails During Rendezvous	68
12	IFF Transponder Failure	72
13	Satellite Navigation Fails	75
14	IFF Interrogator Fails During Air-to-Air Combat	79
15	Fire During Refuel	83
16	AFC Failure (L.L. Penetration)	87
17	TF/TA Failure	89
18	FLIR Fails During A/G Combat	92
19	HUD/VSD Failure	95
20	Designation Control Function Fails. During Air-to-Ground Weapon Delivery	98
21	Multimode Radar MTI/HTT Mode Function Failure	101
22	Precision ILS Fails	106

LIST OF ILLUSTRATIONS (Contd)

<u>Figure No.</u>		<u>Page</u>
23	Brake Failure	109
24	Low Level Penetration (TF/TA)	115
25	Low Level Penetration (TF/TA) (Engine Malfunction)	120
26	Low Level Penetration (TF/TA) (Auto Terrain Following Failure)	124
27	Low Level Penetration (TF/TA) (Navigation Satellite Failure)	128
27	Low Level Penetration (TF/TA) (Navigation Satellite Failure) (Contd) . . .	129
28	Low Level Penetration (TF/TA) (Elect. Distribution Failure)	133
28	Low Level Penetration (TF/TA) (Elect. Distribution Failure) (Contd) . . .	134
29	IIPACS Normal Low Level Penetration	138
30	IIPACS Low Level Penetration - Engine Malfunction	140
31	Normal Low Level Penetration - Engine Malfunction	141
32	IIPACS Low Level Penetration - Auto Terrain Following Failure	143
33	Normal Low Level Penetration - Auto Terrain Following Failure	144
34	IIPACS Low Level Penetration - Nav. Sat. Failure	146
35	Normal Low Level Penetration - Nav. Sat. Failure	147
36	IIPACS Low Level Penetration - Elect. Dist. Failure	149
37	Normal Low Level Penetration - Elect. Dist. Failure	150

LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
I	Channel Time - In-Use Distributions . . .	9

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.

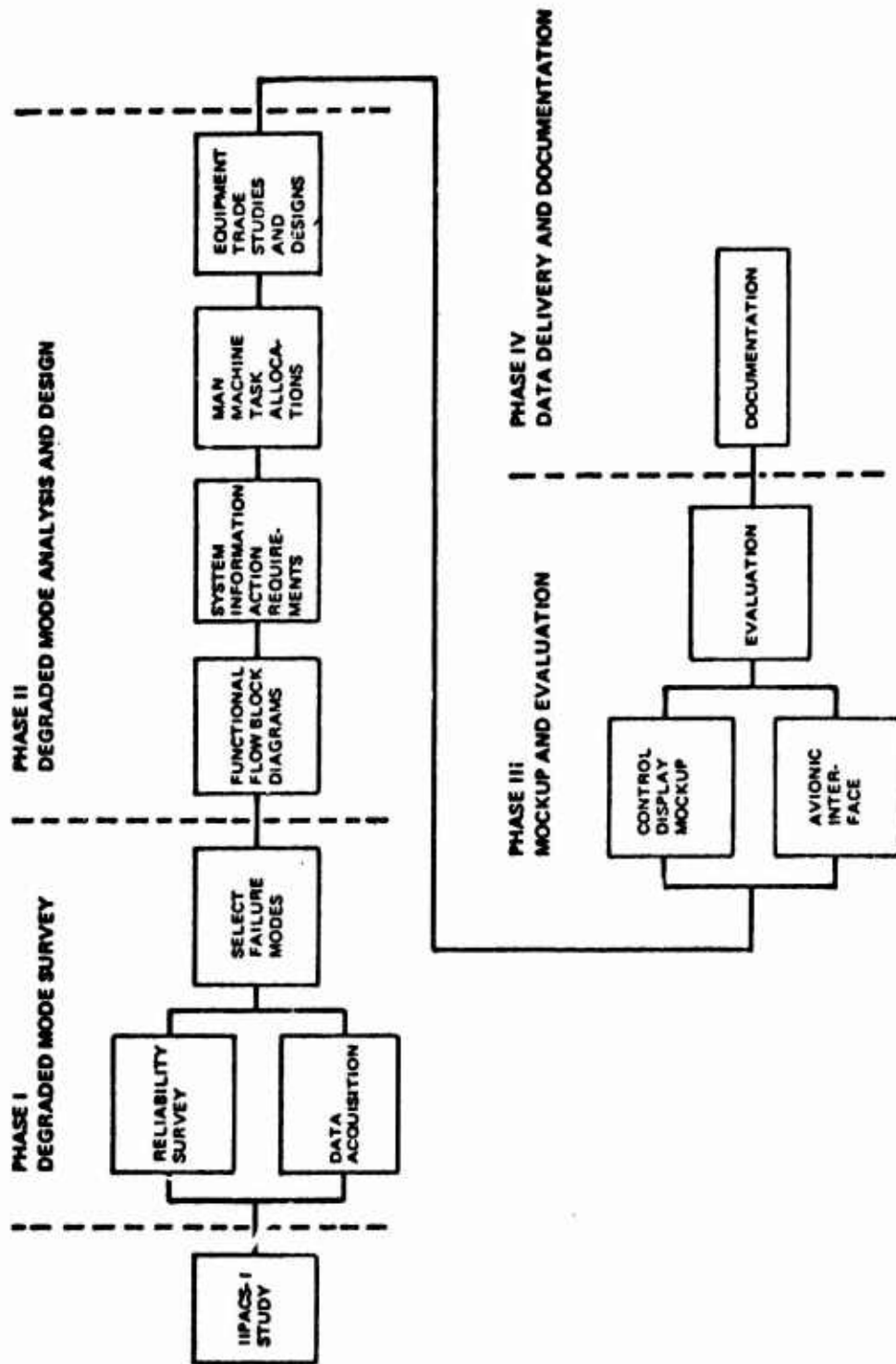


Figure 1. IIPACS-2 Program Flow Chart

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 necessity 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:

- o Engine failure
- o Automatic terrain-following failure
- o Navigation satellite failure
- o 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

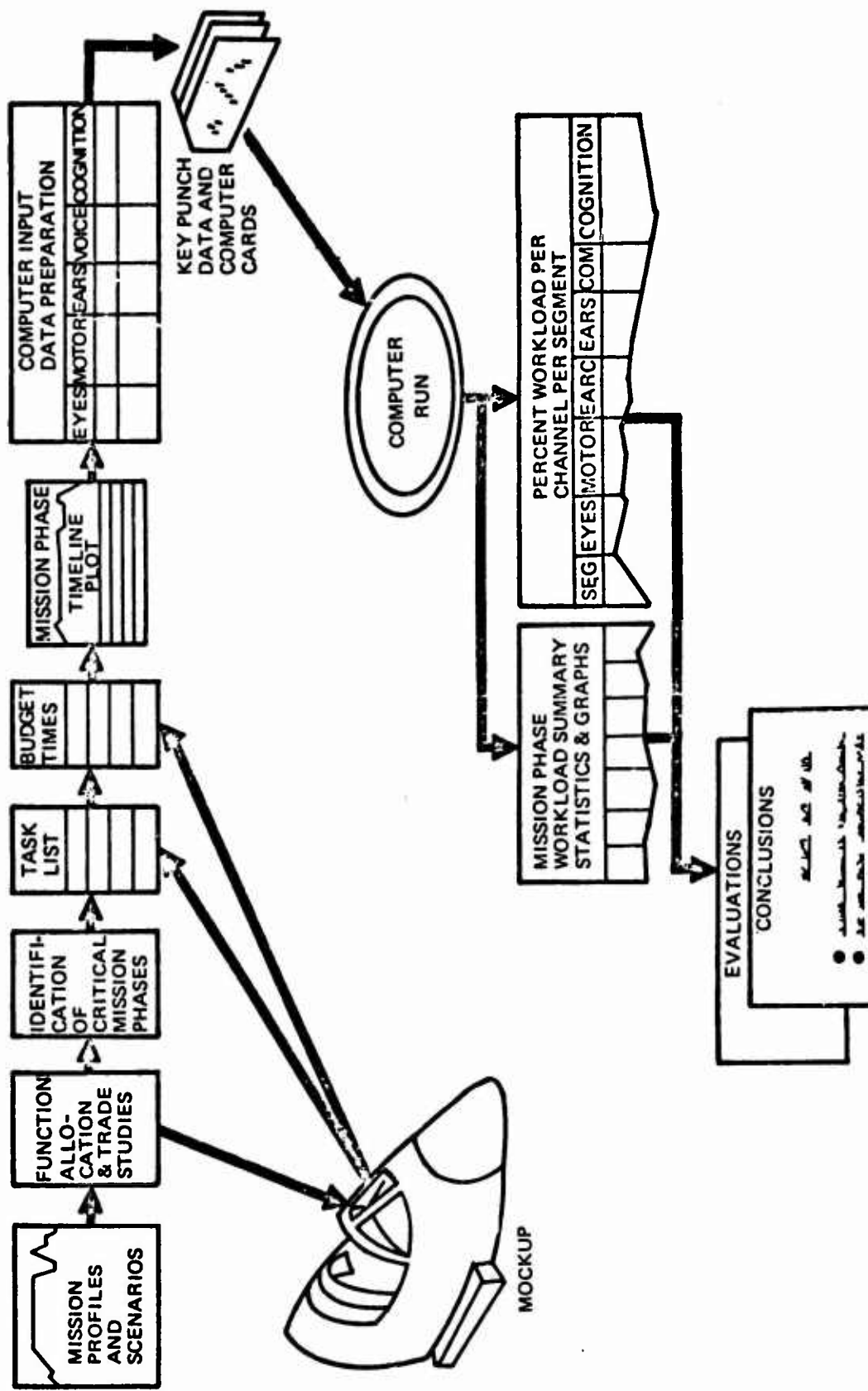


Figure 2. Crew-Workload Evaluation Method

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

<u>Sensory Channel</u>	<u>Task Classification</u>		
	<u>Discrete (%)</u>	<u>Monitor (%)</u>	<u>Continuous (%)</u>
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:

$$S_k = \sum_{i=1}^N W_{cik} \quad K=1,12$$

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

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

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.

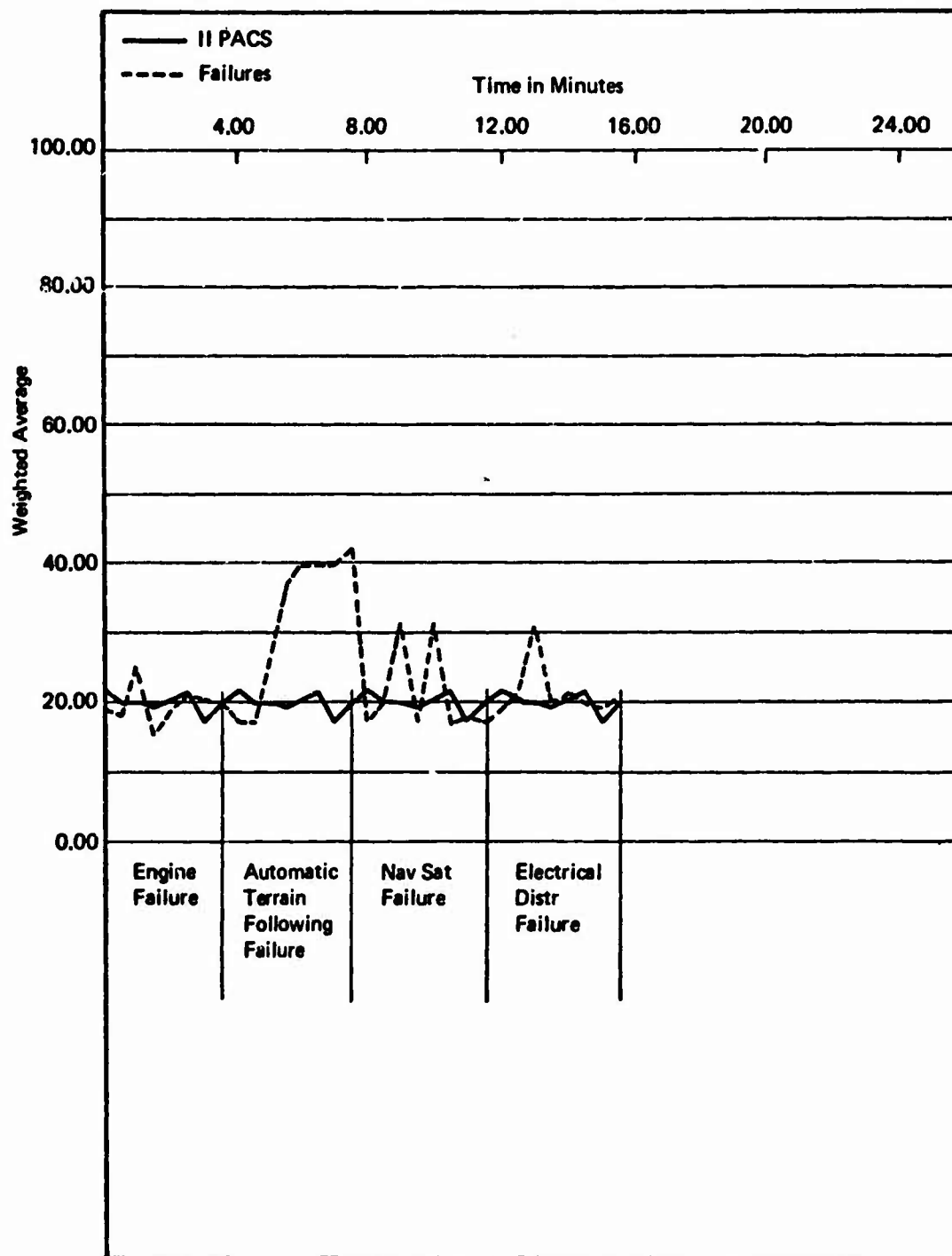
Results

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 contributed 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



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:

- o The IIPACS concept, updated in response to advancing technology, offers a significant advance in tactical weapon system effectiveness.
- o That through a dependent system of automation, a reduction of pilot workload will be realized.
- o That time-sharing techniques, multipurpose controls and displays and integration of information and control functions is feasible.
- o 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.
- o 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)

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

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

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
	32 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 Primary Flight Control Throttle Control CCC	CONTROLS AND DISPLAYS Designation Control HUD/VSD HSD/Map MPD's 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 Primary Flight Control Throttle Control CCC	CONTROLS AND DISPLAYS Designation Control HUD/VSD MPD's HSD/Map 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

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

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

2.2.3 DESCEND FOR LANDING

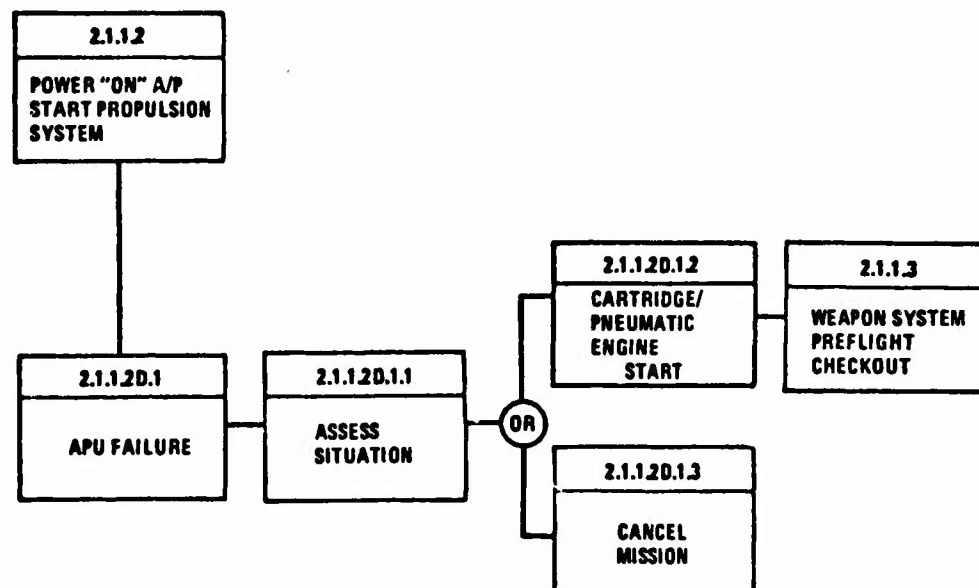
SAFETY OF FLIGHT	MISSION CRITICAL
PROPULSION	
Engine Fire	
Engine Loss	
ELECTRICAL	
Electrical Fire	
AC Power	
DC Power	
AERODYNAMIC CONTROL	AERODYNAMIC CONTROL
Flight Control	High Lift
Wing Sweep	
FUEL	FUEL
Transfer	Indicating
NAVIGATION	
INS	
AUTOMATIC FLIGHT CONTROL	AUTOMATIC FLIGHT CONTROL
SAS	Variable 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	

2.3.4/5 APPROACH AND LAND (Cont)

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 TASKS/ 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. 2. Warn crew. 3. Monitor instructions.	1. FMAC senses fault 2. APU fault elect. and/or mechanism 3. Preprogrammed msg. in storage	MPD MPD	(Storage)	TNC	2.0	Ref. 2.1.1.8 "Communicate"	5.0 5.0 5.0	Machine Machine Man	Note: FMAC operates on display panel as CCC and one of the MPD's.	
	2.1.1.2D.1.1 Assess Situation	1. Consider: FMAC instructions Elect/mech. problem only - no further action Mission importance 2. Decision - Select alternate start method. Note: If not loaded with cartridge start, allow 50 sec. for loading.										
	2.1.1.2D.1.2 Cartridge/Pneu- matic Engine Start	1. Battery "on." 2. Select engine master switch - selected engine for start. 3. Engine start switch to "cartridge start." 4. Initiate starter cartridge/pneumatic. 5. Select "run" position. 6. Select engine parameters. 7. Monitor engine master 2nd engine start. 8. Select engine master switch to "on." 9. Cross bleed "open." 10. Disable 2nd engine cartridge initiator. 11. Engine start switch to "start" on 2nd engine. 12. Sense engine parameters. 13. Monitor engine parameters.	1. Battery available 2. Left engine switch to "on." 3. Left engine "cartridge start" selection 4. Cartridge starter available 5. Throttle position 6. RPM, TIT, EPR, Oil P., FF 7. (Same as above.) 8. Right engine switch to "on." 9. Left and right engine bleed 10. Cartridge disabled 11. Right engine "start." 12. RPM, TIT, EPR, Oil P., FF 13. (Same as above.)	MPD	Engine Start Panel Engine Start Panel Engine Start Panel Engine Start Panel Engine Start Panel	TNC TNC TNC TNC TNC	1.5 1.5 1.5 20.0 1.5		5.0 5.0 5.0 5.0 5.0	Man Man Man Machine Machine Man/Machine Machine Machine Man Machine Man	Require: Battery switch. Require: Redesign of control panel to provide alt. start capability. Note: Electric power for starting and monitoring engine parameters is supplied by battery power. If provided by engine power, it is provided by OTIS, CCC keyboard, and one MPD.	See "Elect Cont Panel" See "Elect Cont Panel"
Ref. 2.1.1.3 Weapon System Preflight Check-out												
	2.1.1.3D.1.3 Cancel Mission	1. APU operate switch "off." 2. Battery switch "off." 3. Exit aircraft.		L. Console L. Console	L. Console L. Console	TNC TNC TNC	1.2 1.2 15.0					

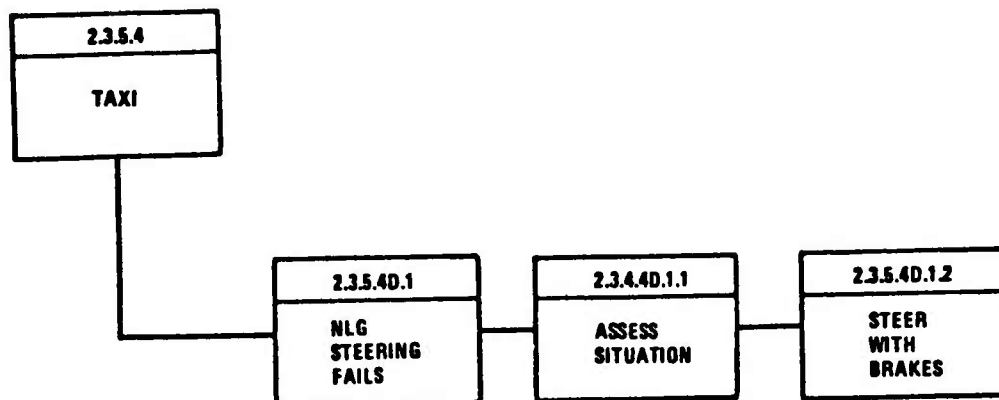


Figure 5. NLG Steering Failure

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. 2. Warn crew. 3. Monitor warning and procedures. 4. Communicate and inform.	1. Fault exists 2. Warning message in storage, voice 3. Reprogrammed instructions to crew 4. Radio available	Master Caution, Voice, Hud/VSD MPD MPD	Storage Comm./Ident. Panel	2.0 TNC	2.0 3.0	Ref. 2.3.5.4 "Taxi" Vol. II " " " "	1.0	Machine Machine Man Man/Machine	Require voice, visual and tactile warning on all systems which affect safety of flight	
	2.3.4.4D.1.1 Assess Multifunction	1. Check manual steer. 2. Consider FIMAC instructions. 3. Decision		MPD MPD	Rudder Pedals	2.0 (Included in (3) above) 2.0	2.0 1.0	" " " " " " " "	2.0 2.0 2.0	Man Man		
	2.3.5.4D.1.2 Steer with Brakes	1. Sense directional information. 2. Present steering information. 3. Monitor ground track. 4. Apply brakes as required to alter heading. 5. Apply opposite brake to stop turn.	1. Steering direction 2. Steering cues 3. Visual cues/heading scale 4. Brake steering available 5. (Same as (4) above.)	VSD/HUD/MPD VSD/HUD/MPD	Brake Pedal (s) Brake Pedal (s)	Continuous 2.0 2.0	1.0 1.0	" " " " " " " "	2.0 2.0 2.0	Machine Machine Man Man Man		

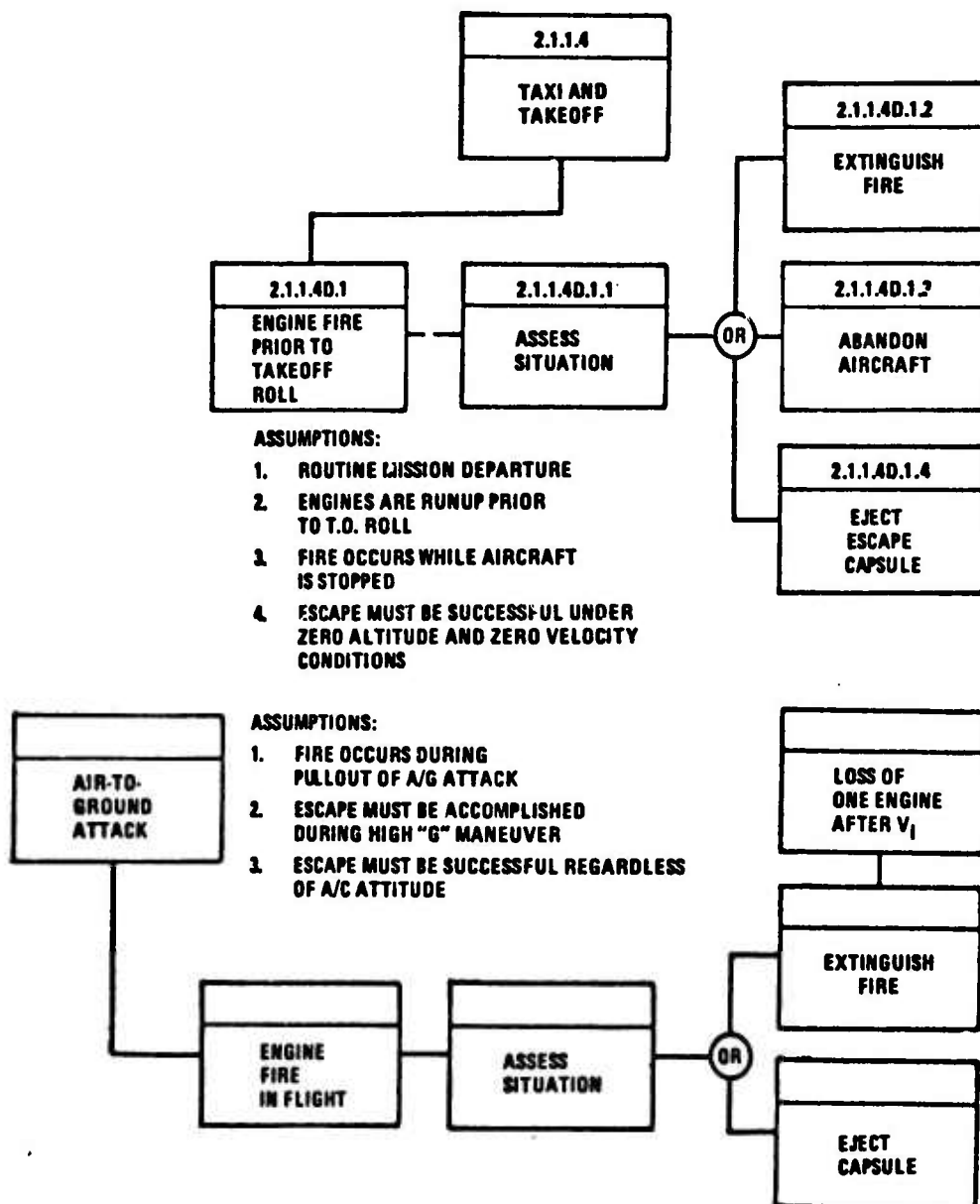


Figure 6. Engine Fire

Degraded Mode: ENGINE FIRE - TAXI

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

Degraded Mode: ENGINE FIRE

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

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

Degraded Mode: ENGINE FIRE				
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
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	Option 1 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	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	
RESPONSE TIME Immediate—remain on as long as condition exists.				
PRECISION REQUIREMENTS Must be highly reliable—capable of long term storage.				
ENVIRONMENT CONSTRAINTS Capsule must operate at "0" altitude, "0" speed, High "g" and High "G"				
LOCATION ALLOCATION				
VISION				
REACH Primary				

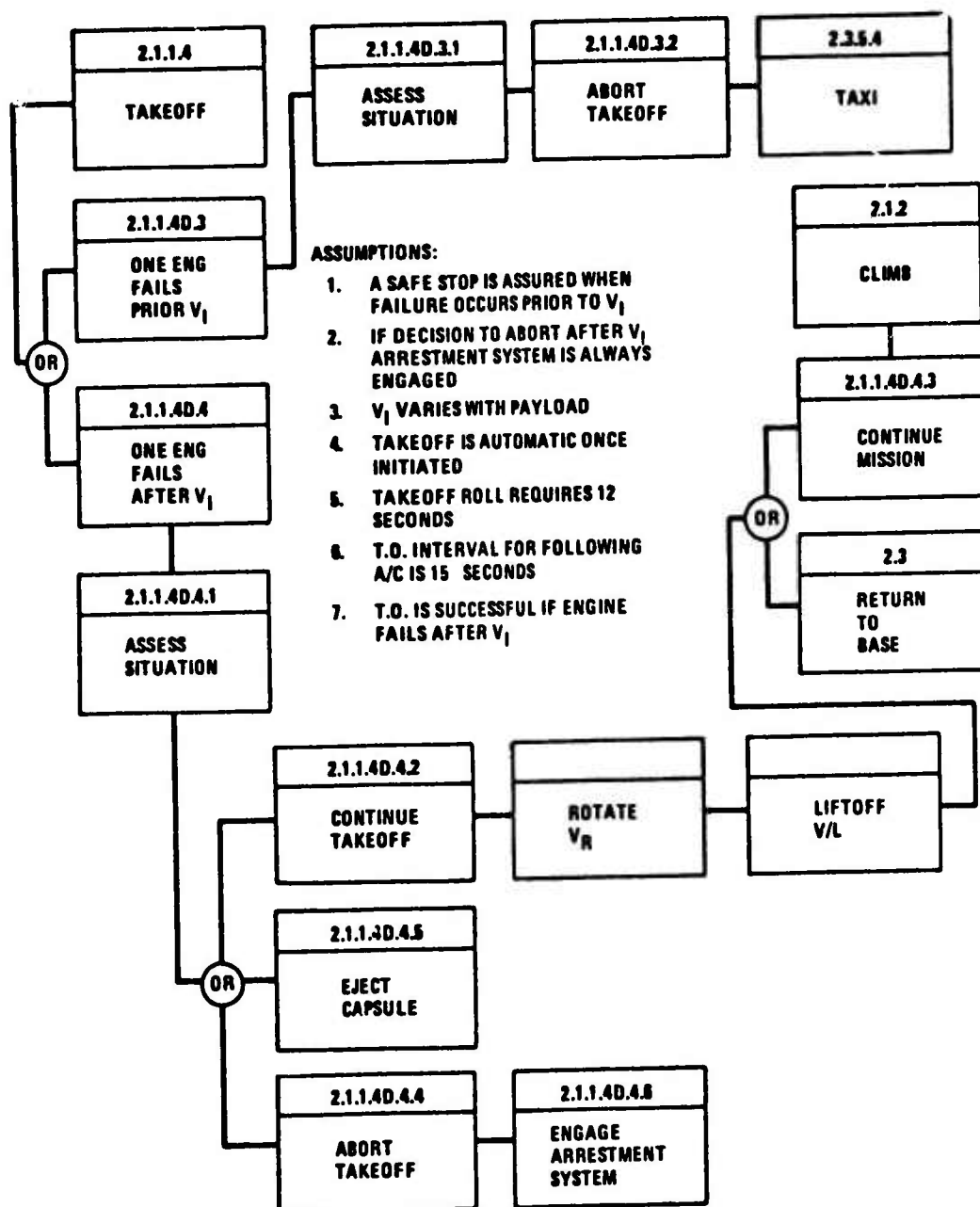


Figure 7. Engine Failure

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 V1	2.1.1.4D.3.1 Assess Situation	1. Detect failure. 2. Warn crew. 3. Monitor warning and procedures. 4. Consider RWY length required to abort RWY conditions Usable RWY remaining 2. Decision - Abort can be accomplished.	1. Thrust/temp./pressure, speed/V1/steering 2. Visual, auditory and tactile 3. Preprogrammed map in storage	Master Caution Voice, VSD/HUD MPD	Comm./Ident FMAC Listen	12.0 sec maximum Included above	1.0 2.0	Ref. 2.1.1.4, Vol. II "Taxi & Takeoff" Monitor Engine Parameters Takeoff Parameters Warning Display	1.0 1.0 1.0	Machine Machine Man	Tact./Voice and video warning recommended Note: Present V1 energy level on items display. Presentation of warning with recommended action. (See trade study attached.)	
		1. Actuate Thrust reverser. 2. Actuate spoilers. 3. Activate wheel brakes. 4. Actuate arrestment device. 5. Steer aircraft. 6. Communicate and inform.	1. Thrust reverser position. 2. Spoiler position. 3. Braking position. 4. Device available 5. Visual/inst. steering cues 6. Radio available (voice)	MPD MPD	L. Console Throttle L. Console Throttle (Spoilers/Speed Brakes) Primary Flight Control No Steer (Rudders) Comm./Ident. Panel & Throttle Microphone	Min. 0 Max. 12.0	1.0	 (May be tail hook or barrier cutting device) Continuous 5.0	Machine Machine Machine Machine Machine Man Man	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.	
		After A/C Comes to Stop 1. Reduce power - stop engine. 2. Shut down - stop engine. 3. Retract thrust reverser. 4. Retract spoilers. 5. Retract arrestment device. 6. Release wheel brakes.		MPD/VSD MPD/VSD	L. Console Throttle L. Console L. Console Throttle L. Console No Primary Flight Control	1.5 3.0 1.5 1.5 1.5	1.5 3.0 1.5 1.5 1.5	None None None None None None	Man Man Man Man Man 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)	
Ref. 2.3.5.4 Taxi												

* R/W - Runway

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

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 RECD	CONCURRENT HEAD 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 2. Warn crew 3. Monitor warning and procedures.	1. Thrust/temp./pressure speed/V ₁ /steering 2. Message in storage (N, voice) 3. Preprogrammed instructions to crew	Master Caution, Voice, VSD/HUD MPD	Comm./Ident, (FMAC Listen)	1.0 1.0 1.0	1.0 1.0 1.0	Ref. 2.1.1.6 "Communicate" " " "	1.0 1.0 1.0	Machine Machine Man	Require. Presentation of warning with recom- mendation to crew.	Voice and video warning presentation and recommendation.
	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. 2. Monitor T.O. parameters. 3. Rotate aircraft. 4. Monitor single engine flight profile. 5. Shut down failed engine. 6. Communicate with tower.	1. Single engine T.O. and flight data 2. Speed/V ₁ /V _R /V _L steering 3. Speed sufficient for T.O. 4. T.O. and performance data 5. Engine master switch actuates windmill brake 6. Radios available	VSD/HUD/MPD VSD/HUD/MPD VSD/HUD/MPD	Primary Flight Controller L Console Comm./Ident Panel	Continuous Continuous Continuous 4.0 TNC TNC	Continuous Continuous Continuous 3.0 5.0	Ref. 2.1.2 "Climb" 2.1.2.1 "Monitor & Control A/C" 2.1.2.2 "Navigate" " " "		Man/Machine Man Man Man		
Ref. 2.1.2 Climb	2.1.1.4D.4.3 Continue Mission	Monitor single engine data and follow squadron doctrine.				TNC	TNC	" " "		Man		
Ref. 2.3 Return to Base	2.1.1.4D.4.4 Abort Takeoff	Ref. Analysis Sheet 2.1.1.4D.1.4 "Eject Capsule"										

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 RECD	CONCURRENT RECD 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. 2. Shut down electrical generating system. 3. Shut down remaining engine.]	1. Systems operating - failed and normal 2. Same as above. 3. Same as above.	MPD MPD MPD	No L. Console L. Console	10.0 TNC TNC	2.0 1.5 3.0			Man/Machine Man Man	Require: Actuation device for power off avionics bus.	See trade study - Toggle Switch on Electrical Control Panel.
Ref. 2.3.5.4 Taxi												

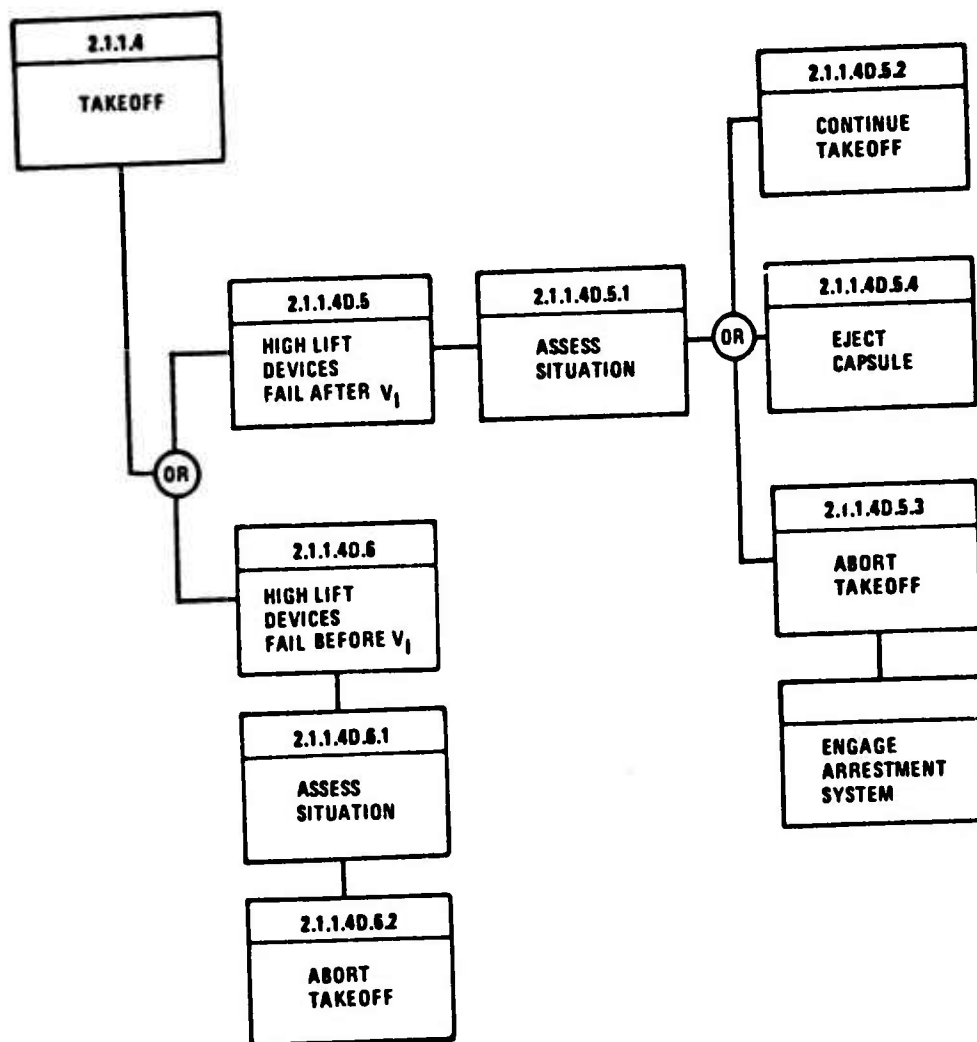
Degraded Mode: ENGINE FAILURE—TAKEOFF

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.	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.	
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					

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: - Simple. - Provides recommended action by video. Con: - Low attention. - Visual cue only provided. - Dependent on other systems.	Pro: - Provides visual and auditory warning. - Redundant. - Provides recommended action by audio and video. Con: - Medium attention. - Dependent on other systems.	Pro: - Multiple warning modes. - Vision, auditory, and tactile stimuli. - Provides recommended action by video and audio. Con: - Complex. - 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 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. 2. Warn crew. 3. Monitor warning and procedures. 4. Determine aircraft controllability.	1. Device position comparison with standard. 2. Visual, auditory and tactile 3. Message in storage 4. Symmetrical or asymmetrical operation	Master Caution, Intercom, HUD/VSD, Tactile HUD/VSD MPD HUD/VSD	Primary Flight Controller	Min. 0 Max. 10.0 	2.0 2.0		1.0 1.0	Machine Machine Man Man	Present warning with recommended action (see trade study "Warning Devices" attached to 2.1.1.4D.3) Note: Cross tie between high lift device normally prevents asymmetric operation.	Tactile/Voice and video warning and recommendation.
2.1.1.4D.5.1 Assess Situation		1. Consider: • R/W length required to abort • Usable R/W remaining • V₁ speed • A/C controllability • FMAC instructions 2. Decision	-			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	Man		
2.1.1.4D.5.2 Continue Takeoff		1. Actuate high lift retraction. 2. Monitor lift device status. 3. Rotate aircraft. 4. Communicate and inform.	1. A/C controllable and high lift devices available 2. Lift device positioning status 3. Speed sufficient for lift-off 4. Radios available	MPD HUD/BSDD-M-D HUD/VSD/MPD	L Console Primary Flight Controller Comm/Ident Panel	TNC TNC TNC	1.5 2.0 2.0 2.0		1.0 1.0 1.0 1.0	Man Man Man 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: RW length required to abort Usable RW remaining Present speed A/C controllability 2. Decision	Same as 2.1.1.4L.5.1				1.0 1.0 1.0 1.0		1.0 1.0 1.0 1.0	Man Man Man Man		
Ref. 2.3.5.4 Task	2.1.1.4D.6.3 Abort Takeoff	See 2.1.1.4D.3.2 "Abort Takeoff"										

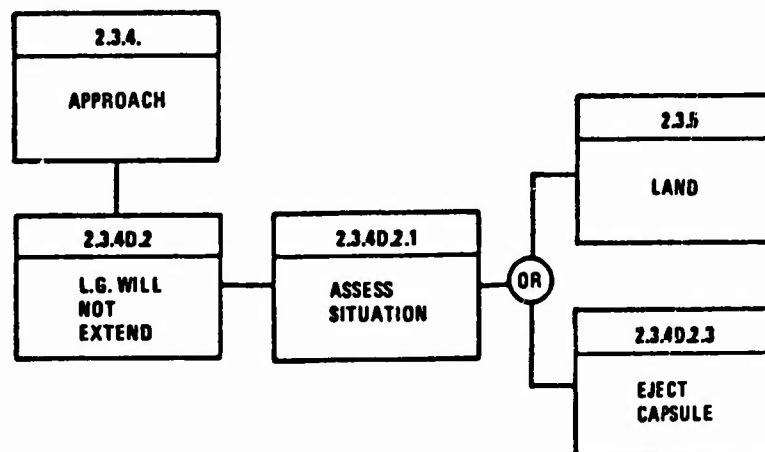
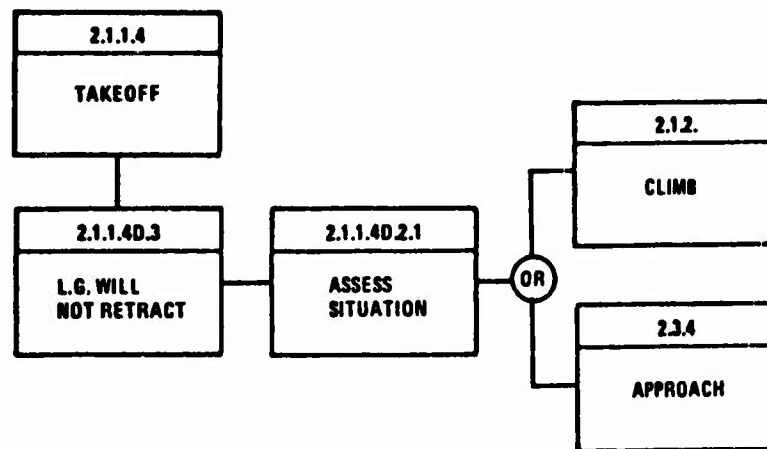


Figure 9. Landing Gear Failure

Degraded Mode LANDING GEAR RETRACTION FAILURE TAKEOFF

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO AVAILABLE WHERE	CONTROL AVAILABLE 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 4 D 3 Landing Gear Will Not Retract		1. Actuate LG* control 2. Detect failure 3. Warn crew 4. Monitor warning and procedures 5. Communicate and inform	1. Control available 2. Compare with standard 3. Visual, auditory 4. Preprogrammed instructions to crew 5. Radio available (voice, D/L)	Master Caution, Voice, VSD/HUD MPD	LG Control (Storage) Comm./Ident Panel & Mic	TNC TNC TNC TNC	1.5 1.0 2.0 5.0	Ref 2 1 1 5 "Monitor & Control A/C" Ref 2 1 1 6 "Communicate" " " "	1.0 1.0	Man Machine Man/Machine Man Man/Machine		
2 1 1 4 D 2 1 Assess Situation		1. Consider Type mission and fuel aboard Which gear is hanging FMAC procedures 2. Decision						" " " " " " " " " " " "				
2 1 1 4 D 2 2 Actuate Emergency Override		1. Actuate LG squelch switch override 2. Observe LG position	1. Squelch switch available 2. Gear position	MPD	No	TNC TNC	1.5 2.0	" " " " " " " " "	1.0 1.0	Man Man	Require Control to override LG squelch switch	See trade study. Mechanical Plunger Actuated by the Pilot
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: - Discrete action required - Can be located in tertiary area Con: - Requires panel space - Requires hood - Requires illumination - Dependent on source of power	Pro - Discrete action required - Can be located in tertiary area Con: - Requires panel space - Requires hood - Requires illumination - Dependent on source of power	Pro - Discrete action required - Can be located in tertiary area - Independent of power source Con: - Requires physical location of solenoid so plunger can be actuated with plunger - Requires panel space - Requires hood - Requires illumination	Option 3 Independent system	

Degraded Mode: LANDING GEAR EXTENSION FAILURE APPROACH AND LAND

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. Warn 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 (visual)	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 TNC TNC Continuous	 1.5 10.0 10.0 2.0 3.0 3.0 3.0 2.0 20.0	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 Man Machine 12.0 Machine 12.0 Man 12.0 Man 12.0 Man/Machine 12.0 Man/Machine 6.0 Man 6.0 Man 6.0 Man Cont Man Cont Man Cont Man	Require Emergency landing landing control. Require Means to individ- ually slave E-O line-of- sight. See trade study attached "Hooded PB Switch" See analysis sheet "L3TV/FLIR Fail" (2.2.3.8D.1) for trade study. * -G Landing Gear ** E-O Electro-optical			
		2.3.4D.2.1 Assess Situation 2.3.4D.2.2 Land Wheels Up 2.3.4D.2.3 Eject Capsule See 2.1.1.4D.1.4, "Eject Escape Capsule" for sequence of events.											
	Ref. 2.3.5 Land												

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

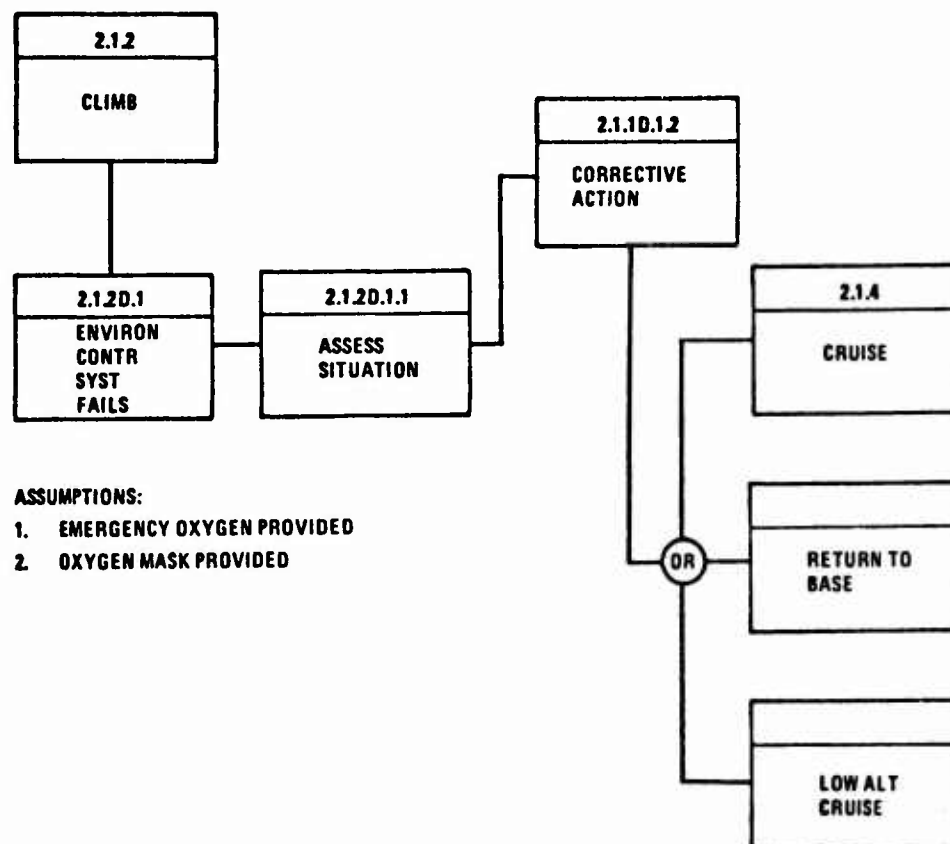


Figure 10. Environmental Control System Failure

FUNCTION/NO CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO AVAILABLE WHERE	CONTROL AVAILABLE WHERE	TASK TIME AVAIL	TASK TIME REQD	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. 2. Warn crew 3. Monitor warning and procedures 4. Alter climb schedule 5. Communicate and inform	1. Sense pressure, temp., contamination & compare with standard. 2. Visual, auditory 3. Warning msg. in storage 4. Autopilot disconnect & hold alt 5. Radios available (voice, D/L)	Master Caution, Voice, HUD/VSD MPD MPD MPD	(Storage) No Comm./Ident Panel & Mic	5.0 5.0 TNC	2.0 3.0 4.0	Ref 2.1.2.1 "Monitor & Control A/C" Ref 2.1.2.2 "Navigate" 	Machine Machine Man Man/Machine Man/Machine	Require Altitude hold Altitude hold Airspeed hold	See revised keyboard "Items" • Airspeed hold • 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 2. Don mask 3. Cycle ECS system 4. Monitor system status	1. Emerg. O₂ supply "On" 2. Masks available 3. ECS "On"/"Off" 4. N. master caution	MPD	ECS Panel (Stowed)	2.0 (Depends on alt.) TNC TNC	1.5 3.0 3.0 2.0	3.0 3.0 3.0 3.0	Man Man Man Man/Machine	See "Fire During Refuel" for requirements	See revised ECS Panel Emerg. O₂ • On (Revised Vol 1 - O₂ Panel) Oxygen blinker to indicate system operation- should be in primary vision area See revised keyboard for
2.1.2D.1.3 System Normal		1. Return to "Climb" schedule	1. Engage "New Steer" and "Alt. CMD"	HUD/VSD/MPD	AFCIS Panel	TNC	3.0	1.0	Man/Machine	Rapid means of selecting course to base	
2.1.2D.1.4 System Abnormal		1. "Return to base" or 2. "Continue mission at low altitude"	1. Select "Base" for new destination 2. Modify preprogrammed mission for altitude change	MPD MPD	Keyboard Keyboard	TNC TNC	3.0 5.0	2.0	Man/Machine	Means to modify flight plan	• "Nav" • Base • Enter or • "Nav" • Modify • Altitude • LapseX • Enter

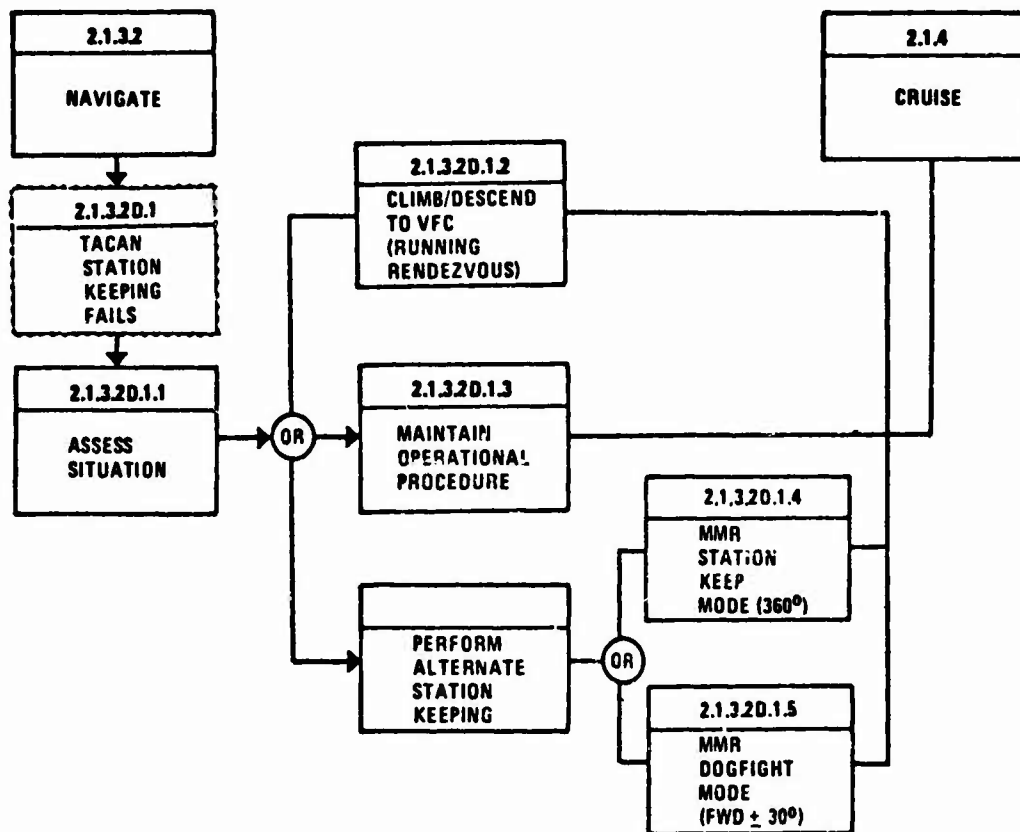


Figure 11. TACAN Station Keeping Function Fails During Rendezvous

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

Degraded Mode: TACAN STATION KEEPING FAILS- RENDEZVOUS

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

Degraded Mode: TACAN STATION-KEEPING MODE FAILS DURING CLIMB AND RENDEZVOUS DESIGN TRADE STUDY				
DISPLAY CONTROL REQUIREMENTS	OPTION NO. 1	OPTION NO. 2	OPTION NO. 3	SELECTION
Select range operation during climb and rendezvous (auxiliary station keeping)	Rotary switch with variable range selection.	Keyboard control	Voice operated	
CRITICALITY				
High	Pro: 1. Simple, positive. 2. Can be turned in either direction. 3. Good visual association. Con: 1. Must provide space for control selection used seldom. 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 use 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 "ECS" 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.
FREQUENCY OF USE				
Low				
RESPONSE TIME				
Medium				
PRECISION REQUIREMENTS				
Not critical				
ENVIRONMENT CONSTRAINTS				
LOCATION ALLOCATION				
VISION				
Secondary				
REACH				
Secondary				

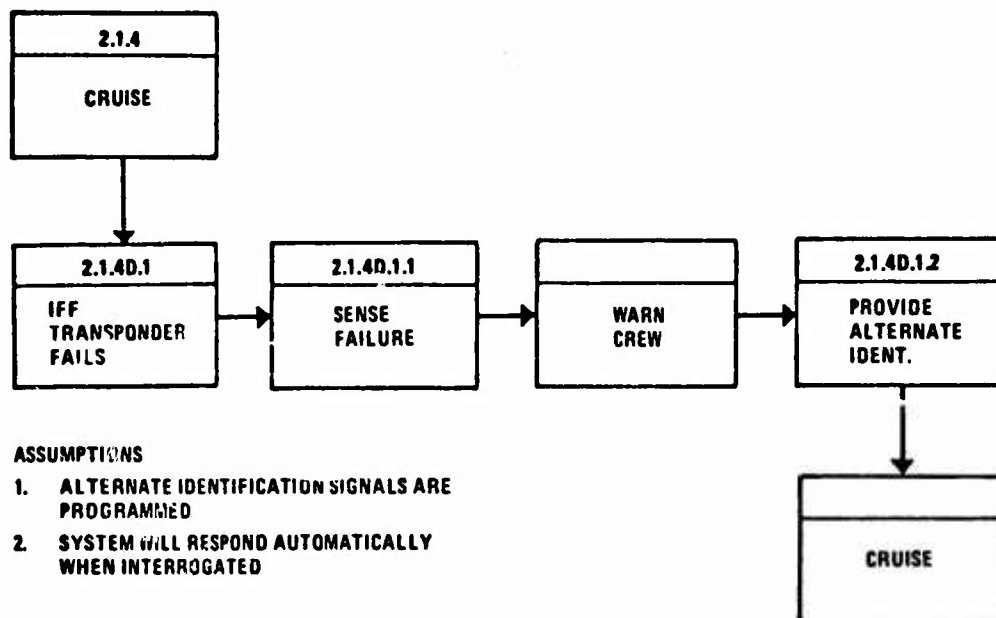


Figure 12. IFF Transponder Failure

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 TASKS/SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TASK RESULTS
Ref 2.2 Combat	(continued)	4th Alternate 1. Make recognition turn on time as required by interrogating station.	1. Communication with interrogating station established Turn direction 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 assigns incoming signals with a discrete identification address. A returned programmer response is provided in the reciprocal direction. Requirements are as follow: 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.												

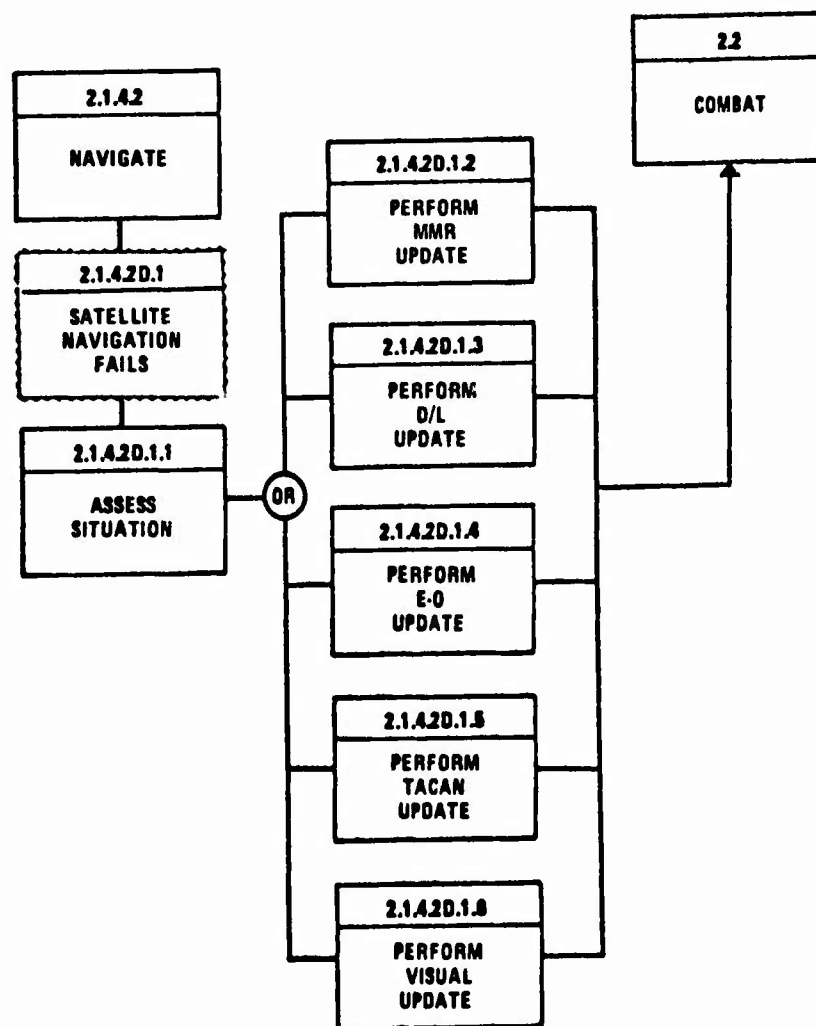


Figure 13. Satellite Navigation Fails

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 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 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. Fault exists 2. Visual, auditory 3. Preprogrammed msg. 4. Radio modes available (secure, clear, voice, D/L) 1. MMR update 2. Precision/NAV CP X X 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 data at flicker rate 8. Cursor/target relative position error 9. Update	Master Caution Voice HUD/VSD MPD MPD MPD MPD --SD/MM HSD/MM	Comm./Ident. Panel No Keyboard No Radar/Map Control Keyboard Designation Control/Voice Designation Control/Voice	TNC TNC TNC TNC TNC TNC TNC 3.0 1.0 1.5 3.0 3.0 2.0 1.5	Ref. 2.1.4 "Monitor & Control A/C" "Identify" - - - - - - - - - -	Machine Man/Machine Man Man/Machine 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5 4.5	Add FMAC warning and volume control to Comm./Ident. Panel Requires means for radar update Recommend addition of "Manual X-Hair lay so that pilot may perform X-Hair lay at his discretion Requires means to flicker radar/map Requires means to control crosshair Requires 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 in 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												

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	INFO AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT TASKS	CONC TASK TIME	TASK/ACTION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
Cont	2.1.4.2D.1.3 Perform D/L Updates	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.	MPD	Comm./Ident Panel Mission Control Keyboard Control Panel Mission Control Panel Designation Control/Voice	TNC TNC TNC TNC TNC TNC TNC	5.0 2.0 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	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. Voice input to CCC. Control Panel for comm/Voice micro phones control Means to select Keyboard Panel.	See revised Mission Control Panel See revised Keyboard. See revised Mission Control Panel Voice input to CCC. Control Panel for comm/Voice micro phones control See revised Keyboard Panel.
	2.1.4.2D.1.4 Perform E-O Updates	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 6. Verify crosshair position. 7. L3 TV/FLIR "On" 8. Activate E-O sensor 9. Select field of view 10. Identify checkpoint in TV/FLIR field of view. 11. Refine crosshair on aimpoint. 12. Activate laser rangings. 13. Activate computer updates.	MPD MPD HSD/Map MPD MPD HUD/VSD HUD/VSD	Keyboard Keyboard Keyboard Keyboard Keyboard No Radar Mode Select Panel Designation Control/ Voice	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 2.0 3.0	Same as "Ref 2.1.4" above " " " " " " "	7.0 7.0 7.0 7.0 7.0 7.0 7.0	Man Man Man Man/Machine Machine Man Man Man Man Man/Machine Man	Means to select E-O NAV update Means to auto or manually lay crosshair Means to select steerable L3 TV or FLIR Means to drive crosshair Means to select voice as secondary Means to NAV update. Require: Means to update with TACAN Require: Means to perform update Require: Means to update visually. Require: Means to perform update.	See revised Keyboard NAV - Crosshair Lay - See revised ground ref. point See revised Laser Rangings "On-Off -" Designation control as voice secondary See revised designation control - update switch added. See Keyboard Control "NAV" - TACAN update. Designation Control o NAV Update o voice on throttle o Mic o Computer Add to Keyboard Cont "NAV" - visual update Designation Control Update - is primary when secondary (on throttle control)
Ref 2.2 Combat	2.1.4.2D.1.5 Perform TACAN Updates	1. Select TACAN NAV update. 2. Select TACAN station. 3. Verify station 4. Monitor in range. 5. Verify location. 6. Activate update.	MPD MPD HSD/Map	Keyboard Keyboard Comm./Ident Panel	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 Require: Means to update visually. Require: Means to perform update.	See Keyboard Control "NAV" - TACAN update. Designation Control o NAV Update o voice on throttle o Mic o Computer Add to Keyboard Cont "NAV" - visual update Designation Control Update - is primary when secondary (on throttle control)
	2.1.4.2D.1.6 Perform Visual Updates	1. Select update method. 2. Set in ground ref. coordinates. 3. Select update when over ground ref. point.	MPD MPD HSD/Map	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.	See Keyboard Control "NAV" - visual update Designation Control Update - is primary when secondary (on throttle control)

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

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		OPTION NO. 1	OPTION NO. 2	OPTION NO. 3	SELECTION
Command X-Heir to drive in range, azimuth and elevation		Voice augmented X-Heir control.	Designation control.	Light pen method for target designation	
CRITICALITY	High	Pro: 1. Leaves hands free to do other tasks. 2. Little physical movement required. 3. No panel or control space use.	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.	Pro: 1. Direct interface with man and display. 2. Can perform with glove.	Option No. 2 Designation control is primary with voice as backup.
FREQUENCY OF USE	High				
RESPONSE TIME	High				
PRECISION REQUIREMENTS	High	Con: 1. Need to insert voice signature cards into the computer. 2. Interferes with other communications.	Con: 1. Takes space when used. 2. Requires a hand to operate which may require other functions as well.	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.	
ENVIRONMENT CONSTRAINTS					
LOCATION ALLOCATION					
VISION Primary					
REACH Primary					

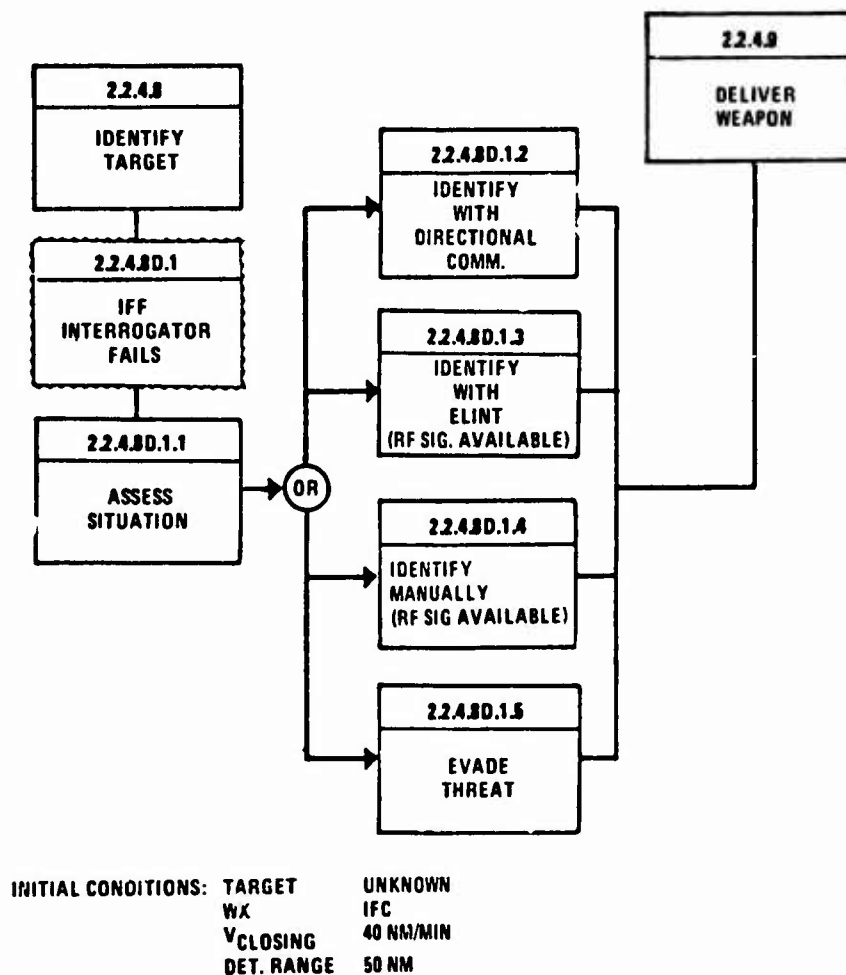


Figure 14. IFF Interrogator Fails During Air-To-Air Combat

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 REDD	CONCURRENT REDD. SYSTEM TASKS	CONC MAN 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. I/R/F emissions 2. N and discrete information 3. MMR track & A/I/A IFF avail.	MPD/HSD	No			Ref. 2.2.4.1 "Monitor & Control A/C" "Navigate" & "Provide Identity"		Machine Man/Machine Man/Machine	Provide means to manually interrogate bogey with MMR	See revised Comm./ Ident. Panel. Illuminated push button and IFF On/Off • IFF Interrogate • 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 CQC instruct. 5. Radio available (voice & D/L)	Master Caution, Voice, HUD/VSD MPD MPD	(Storage) Comm./Ident. Panel & M.C.		1.0 3.0 5.0	" "	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 (included in (3) above) 15.0	2.0 2.0 2.0 2.0 2.0	" "	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-hairs 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	3.0 3.0 1.5 1.5	" "	3.0 3.0 3.0 3.0	Man Man Man Man Man Man	Requires alternate means to interrogate aircraft (other than radar). Requires means to monitor IFF response.	See revised Comm./ Ident. 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 RECD	CONCURRENT REQD SYSTEM TASKS	CONC MAN TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
(cont)	2.2.4.BD.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				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.	Use Keyboard Control ATA A/A threats
	2.2.4.BD.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-bears 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	TNC 20.0 20.0 20.0 20.0 20.0	3.0	-- -- -- -- --	5.0 5.0 5.0 5.0 5.0	Man Man Man Man/Machine Man/Machine	Require appropriate symbolology for threat priority position & status. Request pen aids instructions. Provide means to request command & negation to assist in identity.	Threat Status/Unknown Position Status Pen Aids Instructions Eradicate/Degrade 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.BD.1.5 Eradicate Threat	1. Alter course and speed to increase bogy 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	AFCSS 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 A/CSS Panel Autopilot On/OH 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	<u>Pro:</u> 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. <u>Con:</u> 1. Must be looked at to operate. 2. Lamps may fail.	<u>Pro:</u> 1. Good space factor. 2. Compatible with digital equipment. 3. Hand can stay in common area while performing other tasks. <u>Con:</u> 1. Takes too long for a single operation. 2. Must look at an MPD for interrogate status.	<u>Pro:</u> 1. Simple motion 2. Good space factor. 3. Does not require visual coordination for operation. <u>Con:</u> 1. Cannot use with DL. 2. Separate lighting.	<u>Pro:</u> 1. Leaves hands free to do other tasks. 2. No panel space used. <u>Con:</u> 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
FREQUENCY OF USE Medium					
RESPONSE TIME					
PRECISION REQUIREMENTS Low					
ENVIRONMENT CONSTRAINTS None					
LOCATION ALLOCATION					
VISION Primary					
REACH Primary					

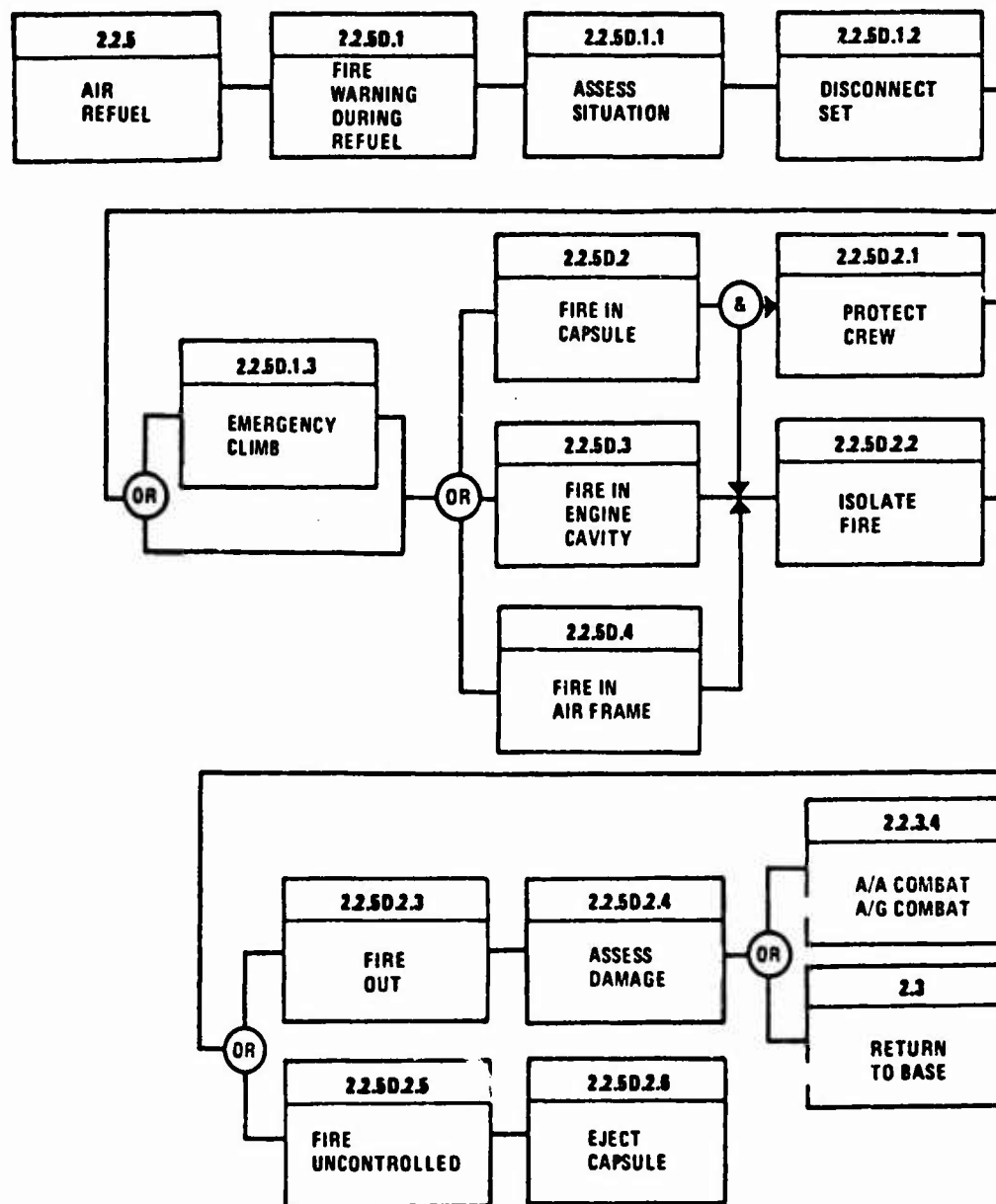


Figure 15. Fire During Refuel

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 None	Machine Man/Machine Man Man/Machine		
2.2.5D.1.1 /ress Situation		1. Consider - Emergency procedures SOP requires disconnect so as not to endanger other aircraft. 2. Decision - Disconnect.								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 mode will disconnect boom/drogue.		No	1.0 2.0 5.0	1.0 1.5 2.0	" "	None None None	Man Man/Machine Man	Require: In-flight refuel break-away control. See trade study(attach) 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. Following actions will be possible: 1. Max thrust 2. Optimum of attack 3. Steering signals 4. Retract speed brakes 5. Close refuel door	"Items" Modify keyboard A/A intercept Enter Following actions will be possible: 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		1. Activate emergency O ₂ 2. Don masks. 3. Dump pressurization.	1. Flames/smoke in cockpit 2. Mask available 3. Dump and 450 ft altitude		ECS Panel (Stowed) ECS Panel	1-5.0 3.0 2.0	1.5 3.0 1.5	" "	None 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 affected system. 2. Activate fire suppressant system. 3. Observe results.	1. Avoids bus "non-essential off" 2. CO ₂ bottles 3. Fire/smoke subsides		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 MAIN TASKS TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TRADE RESULTS
(continued)	2.2.50.3 Fire in Engine Cavity	"Isolate and Fight Fire" See 2.2.50.2.2. above	1. Fire or overheat no longer exists	Fire Warning VSD/HUD/MPD		TNC	5.0	Ref 2.2.5.2 "No Fuel" Ref 2.2.5.1 "Monitor & Control A/C"	2.0	Man/Machine		
	2.2.50.4 Fire in Air Frame	"Isolate and Fight Fire" See 2.2.50.2.2. above	1. Avionics power "On" of electrical avionics 2. FMAC status end-to-end check of systems 3. Subsystem status 4. Alternate sources presented 5. Based on above results	MPD MPD	Elect Power Control Panel Keyboard	TNC	1.5	Ref 2.2.5 "Air Refuel"	10.0	Man/Machine	Request: Improved means of tasking system to LRU level - requested by pilot	See revised FMAC keyboard controls - "FMAC"
	2.2.50.2.3 Fire Out	1. Sense fire/overheat 2. Present data 3. Decision: Fire out				TNC	4.0	..	10.0	Man/Machine		
	2.2.50.2.4 Aircraft Damage	1. Reactivate systems 2. Activate FMAC systems test 3. Present data 4. Provide alternate source for critical systems 5. Decision: Continue mission or return to base				TNC	20.0	..	10.0	Man/Machine		
	2.2.50.2.5 Fire Uncontrolled	1. Sense fire/overheat 2. Present data 3. Observe data 4. Decision: Fire uncontrolled 5. Decision: Eject	1. External/internal 2. Fire/overheat warning(s) persists 3. Visual fire smoke/still exists 4. Fireman communicates fire engaging A/C or A/C is uncontrollable 5. Based on facts above 6. See "Eject Capsule"	Fire Warning, Voice VSD/HUD/MPD, Tactile Visual		Continuous	2.0	Ref 2.2.5 "Air Refuel"	10.0	Man/Machine		
Ref 2.2.3/4 Attack/Combat Ref 2.3 Return to Base	2.2.50.2.6 Eject/Escape	Reference: Analyst Sheet 2.1.1.4D : 4 "Eject Escape Capsule"				Continuous	1.0 1.0	..	None None	Man Man		

Degraded Mode: FIRE - REFUEL		DESIGN TRADE STUDY			
DISPLAY/CONTROL REQUIREMENTS		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
INFLIGHT REFUEL BREAK-AWAY CONTROL					
CRITICALITY					
FREQUENCY OF USE Infrequent		Pro: 1. Conveniently located. 2. Simple. 3. Permits option of "Go"/"No Go." 4. Reacts well in contingencies. 5. Tactile cue eliminates display	Pro: 1. Fast reaction 2. No decision making delay. 3. Can sense small changes in stimuli.		Option No. 1 1. Provides positive control. 2. Simple. 3. Discretionary.
RESPONSE TIME Rapid					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. Displace 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.
PRECISION REQUIREMENTS					
ENVIRONMENT CONSTRAINTS		Con: 1. Requires crew decision. 2. May be time critical. 3. Requires discrete action. 4. Must be reset.	Con: 1. Requires display. 2. Complex 3. Can execute only as programmed 4. Sensitive to false signals.		
LOCATION ALLOCATION					
VISION					
REACH Primary					

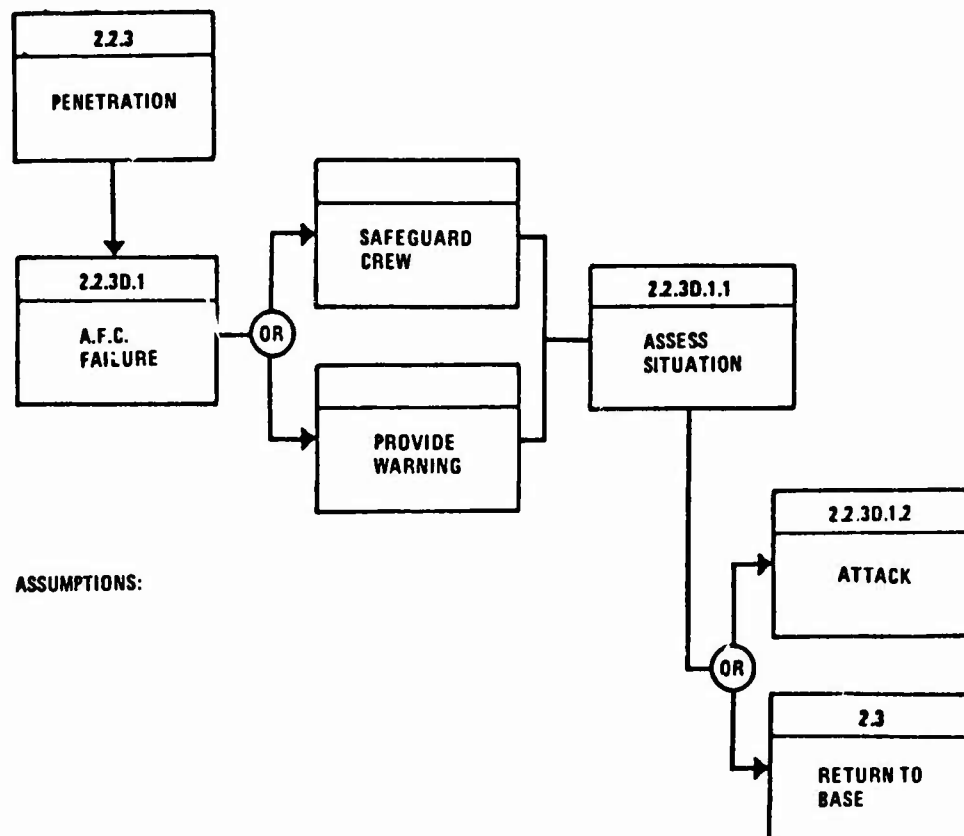


Figure 16. AFC Failure (L. L. Penetration)

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

FUNCTION NO CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO C/L WHERE	CONTROL C/L WHERE	TASK TIME AVAIL	TASK TIME RECD	CONCURRENT RECD 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)		Assume: Autopilot engaging function fails.										
2.2.3D.1 Autopilot Failure		1. Detect Failure 2. Warn crew. 3. Monitor warning and procedure. 4. Safeguard crew. 5. Communicate and inform BAC	1. Fault exists in AFCS 2. Visual, auditory 3. Preprogrammed instructions to crew 4. Preprogrammed action 5. Radio voice/DL modes avail.	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.	
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 2. Decision		MPD MPD HUD/VSD 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.1.2 Continue Mission in Degraded Mode or 2.3 Return to Base		1. Reset master caution. 2. Return 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		

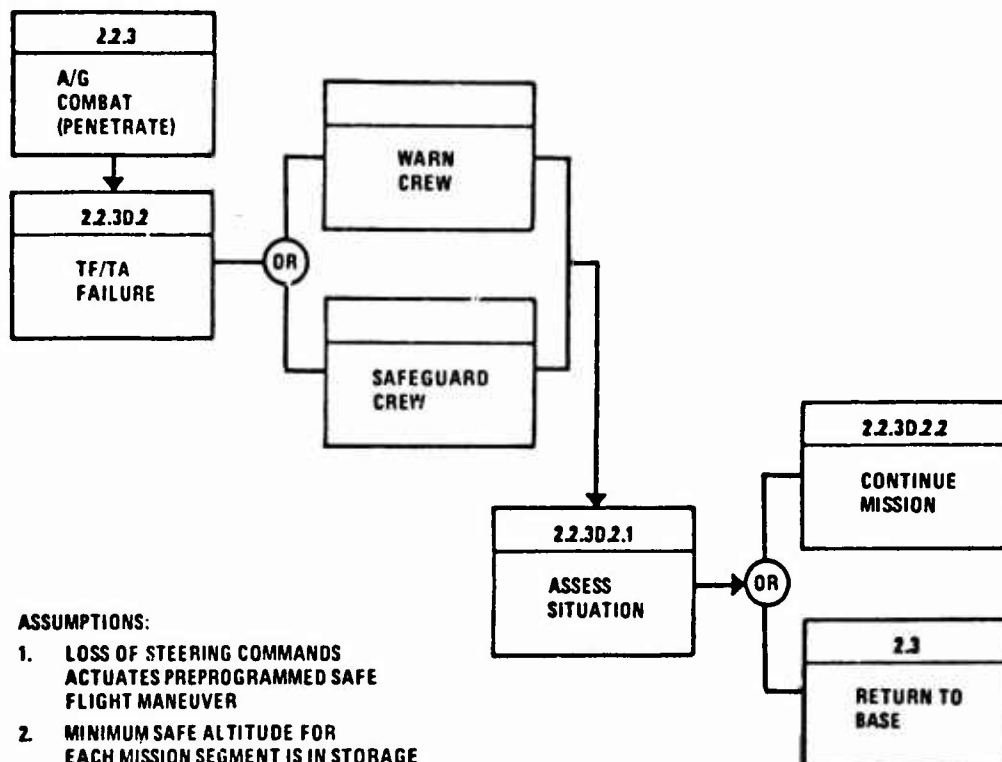


Figure 17. TF/TA Failure

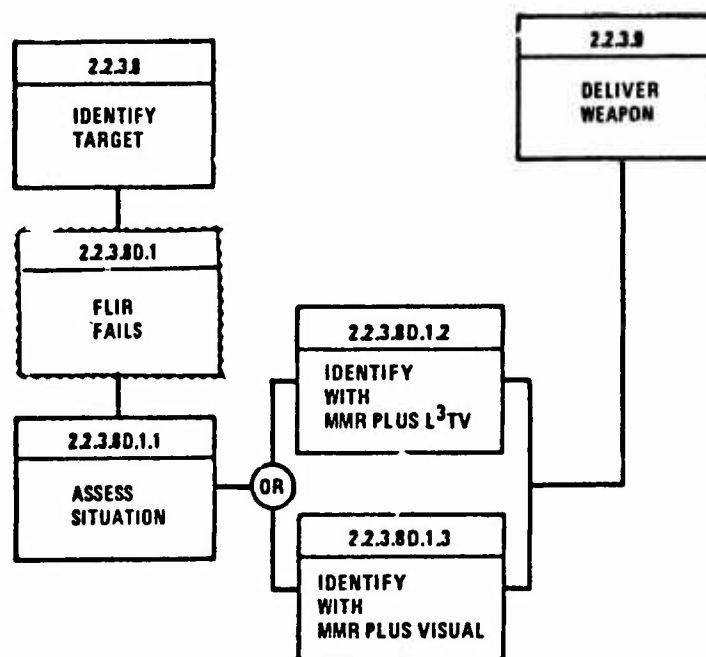
Degraded Mode: TF/TA FAILURE - A/G COMBAT (L.L. PENETRATION)

FUNCTION NO. CONDITION	ALTERNATIVE ACTIONS	TASK/ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	INFO. AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME REQD	CONCURRENT SYSTEM TASKS	CONC MAN TASK TIME	TASK/ACTION ALLOCATION	NEW DISPLAY/CONTROL REQUIREMENTS	DESIGN TABLE 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 proceedure. 5. Communicate and inform BAC.	1. Fault exists 2. Visual, auditory and tactile 3. Preprogrammed A/C climb 4. Preprogrammed instructions to crew 5. Radio voice/DL modes avail.	Master Caution, Voice, HJDN/SD MPD	No No	TNC	3.0	Ref. 2.2.3 "Provide Identity" "Monitor & Control A/C" "Monitor Enemy Activity"		Machine Machine Machine Man Man/Machine	Require means to shut off warning. Require means to insert min-imum IFC altitude. Require means to insert manually preprogrammed in storage.	Trade Study Master Caution Reset (Push Button Control) Keyboard "Items" Min. IFC Alt; Numeral XXX Enter
	2.2.3D2.1 Assess 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 MPD	Comm./Ident. Panel	15.0 15.0 15.0 15.0	2.0 2.0 1.0 Included in (4) 2.0 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		
Ref. 2.3 Return to Base	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 MS- 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.									

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

DESIGN TRADE STUDY

DISPLAY CONTROL REQUIREMENTS		OPTION NO. 1	OPTION NO. 2	OPTION NO. 3	OPTION 4	SELECTION
Master Warning Reset		Push Button	Toggle Switch (spring loaded)	Keyboard	Voice	
CRITICALITY	Pro:					Option 1
Medium						
FREQUENCY OF USE	Pro:	1. Could serve as master caution. 2. Rapid single action. 3. Conforms with general design concept	Pro: 1. Separate caution signal required. 2. Rapid single action.	Pro: 1. No additional panel space required.	Pro: 1. No panel space required. 2. No lighting required.	For degraded mode, voice control for normal mode.
Medium						
RESPONSE TIME	Con:		Con:	Con:		
Medium						
PRECISION REQUIREMENTS						
High	Pro:	1. Must be lighted. 1. 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						



ASSUMPTION

TARGET: ARMORED VEHICLE
 WEATHER: MARGINAL VFR
 ALTITUDE: 1000 FT AGL

Figure 18. FLIR Fails During A/G Combat

DESIGN TRADE STUDY				
Degraded Mode: FLIR FAILS DURING AIR TO GROUND COMBAT		OPTION NO. 1		
DISPLAY/CONTROL REQUIREMENTS		OPTION NO. 2		
Synchronize all sensors to a common line-of-sight.		OPTION NO. 3		
SELECTION		OPTION NO. 3		
Option 3		Illuminated push buttons.		
Illuminated push buttons with "Bore-sight," "Slow," or "Independent" in a readily accessible area. Normal switch position will "Bore-sight."		Note: "Bore-sight" mode will be the normal switch position which synchronizes all radar and electro-optical sensors to a common line-of-sight.		
L3TV/FLIR sensor pointing angles will slow at "0" azimuth and elevation angles on "Slow" command.		In the "Independent" mode the L3TV/FLIR pointing angles will be slaved independently of the radar constraint when directed by the tracking control.		
Option 3		Illuminated push buttons.		
Illuminated push buttons with "Bore-sight," "Slow," or "Independent" in a readily accessible area. Normal switch position will "Bore-sight."		Note: "Bore-sight" mode will be the normal switch position which synchronizes all radar and electro-optical sensors to a common line-of-sight.		
L3TV/FLIR sensor pointing angles will slow at "0" azimuth and elevation angles on "Slow" command.		In the "Independent" mode the L3TV/FLIR pointing angles will be slaved independently of the radar constraint when directed by the tracking control.		

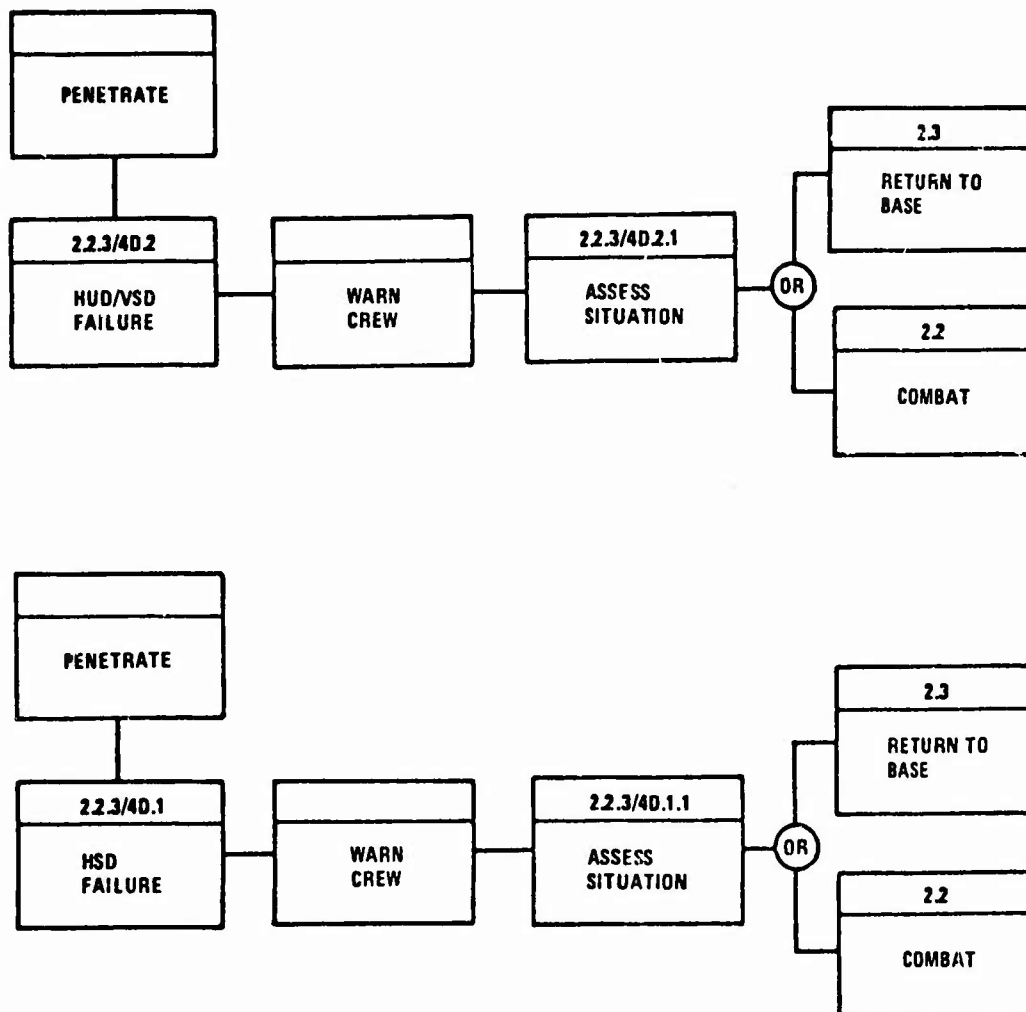


Figure 19. HUD/VSD Failure

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 REDD	CONCURRENT REDD 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 2. Warn crew 3. Monitor FMAC instructions 4. Communicate and inform	1. FMAC detects deteriorating signals 2. Visual, auditory 3. Programmed msg. in storage 4. Radio modes available (voice, D/L)	Master Caution Voice Call/HUD MPD	(Storage) Comm/dem. Panel	5.0 5.0 TNC	1.0 3.0 (Optional)	Ref. 2.2.3/4 "Navigate" and "Monitor Enemy Activity"	2.0 2.0 2.0	Machine Man/Machine Man Man/Machine		
	2.2.3/4D.1.1 Assess situation	1. Consider: Fault Environment Mission Requirements Alternate Display: FMAC Instructions 2. Decision						"		Machine		
	2.2.3/4D.1.2 Select alternate displays (Auto/ Manual)	1. Take corrective action to prevent subsequent system damage. 2. Transfer HSD information to VSD and transfer VSD information to HUD. 3. Observe HSD information or manual. 4. Select MPD for HSD information. 5. Observe HSD information.	1. Affected display shutdown 2. HSD transfer function available 3. HSD symbology/video 4. MPD available for HSD info. 5. HSD symbology/video	MPD Ss acted	FMAC/CCC No No		1.5 2.0 5.0 2.0	" " " "	2.0 2.0 2.0 2.0	Machine Man/Machine Man Man/Machine Man	Redesign IPACS 1 for greater flexibility among primary displays Redesign IPACS 1 MPD format to provide greater flexibility and more rapid operation	Push Button Control "HSD Transfer" On Keyboard "C/D" HSD Transfer HSD to MPD No. XX Enter
Ref. 2.2 Return to Base Ref. 2.2 Combat											Note: Recommend changing No. 5 at type display to same as MPD 1 through 4	

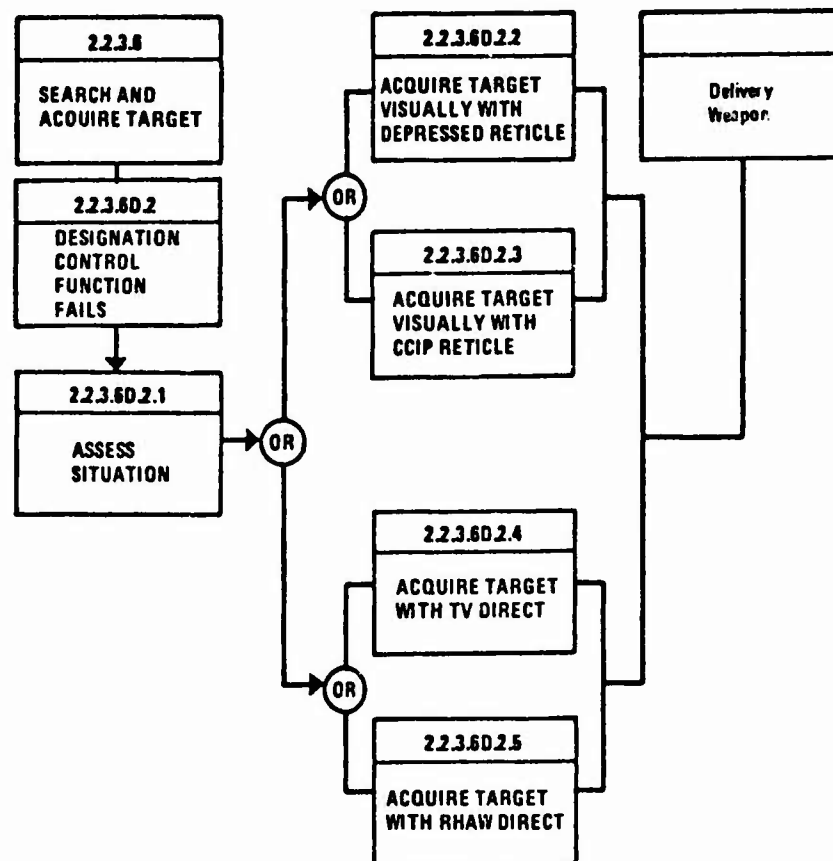


Figure 20. Designation Control Function Fails During Air-To-Ground Weapon Delivery

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. 3. Monitor FMAC instructions.	1. Fault exists 2. Visual, auditory 3. Preprogrammed msg. in storage	Master Caution, Voice, HUD/VSD MPD	(Storage)	5.0 5.0	1.0 3.0	Ref. 2.2.3 "Monitor & Control A/C" "Navigate," "Provide Identity" and "Monitor Enemy Activity"	3.0 3.0	Machine Man/Machine Man	Add "EMAC Warn" volume control to comm/ident. panel.	
2.2.3.6D.2.1 Assess Situation		1. Consider: Fault Alternative controls Accuracy requirements Target type Environment FMAC instructions 2. 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 2.0 (Included in (3) above)	" " " " " " "	4.0 4.0 4.0 4.0 4.0 4.0 4.0	Man Man Man Man Man Man Man		
2.2.3.6D.2.2 Perform Manual Depressed Reticle Bombing (Estimate Weapon)		1. Select and monitor weapon. 2. Select delivery method. 3. Select delivery maneuver. 4. Select type release. 5. Air-to-ground combat 6. Insert nui settings. 7. Locate target – moving or fixed. 8. Maneuver aircraft for attack. 9. Position pipper on target. 10. Perform manual delivery maneuver and monitor parameters.	1. Store available and status 2. Depressed reticle 3. DIVE, time, level, OTS, etc. 4. Manual/auto 5. Air-to-ground combat 6. ± mil depression 7. Target detected by visual/ visual aided sensors. 8. Items (pitch and roll commands) 9. Target visible, depressed reticle visible 10. Dive angle, EAS, release altitude	HUD/VSD HUD/VSD HUD/VSD HUD/VSD	SMS Panel No No SMS Panel Keyboard No AFCIS/Manual (See (B) above)	20.0 20.0 20.0 20.0 20.0 20.0 20.0	1.5 1.5 1.5 1.0 3.0 4.0 3.0	Ref. 2.2.3 "Provide Identity" and "Monitor Enemy Activity" " " " " " " "	5.0 5.0 5.0 5.0 5.0 5.0 5.0	Man Man Machine Man Man Man Man/Machine Man/Machine Man/Machine Man/Machine	Note: Assume at least one program has been selected for each store – prior to takeoff. SMS – Add "Depressed Reticle" to keyboard SMS – Add "Delivery Maneuver" with options to existing keyboard Use existing AFCIS panel for control stick steering (CSI). Review AFCIS panel to include this type steering any time autopilot is "On."	

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 RECD	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 type release. 4. Select type release. 5. Select desired CEP. 6. Launch target. 7. Maneuver A/C and position CCIP reticle on target.	1. Stores available and status 2. CCIP 3. Dirs, level, loss 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 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 type release. 4. Select type release. 5. Monitor WPN TV caging. 6. Monitor WPN TV video. 7. Maneuver A/C to acquire target. 8. Unstage TV guidance.	1. Stores available and status 2. WPN TV 3. Conversion 4. Manual 5. Caging/unstage status 6. Adversity signal level 7. Items (pitch and roll) 8. Contrast lock-on	MFD HUD/VSD HUD/VSD	SMS Panel No Keyboard Control SMS Panel Primary Flight Control No	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	Man Man Machine Man Machine Man Man/Machine Man	"SMS" - Add WPN TV to delivery method on existing keyboard. Requires means for WPN TV "Contrast Lock-on."	Designation Control o Lock-on/Reject o E-O Aux. Sensor Covered o Contrast L.O. 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 type release. 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 modes, 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	1.5 3.0 1.5 3.0 3.0 1.0	" " " " " "	4.0 4.0 4.0 4.0 4.0 4.0	Man Man Machine Man Machine Man/Machine Man	"SMS" - Add ARM to Delivery Method select on keyboard.	
			(1) CCIP - Continuously Computed Impact Point (2) ARM - Anti-Radiation Missile									

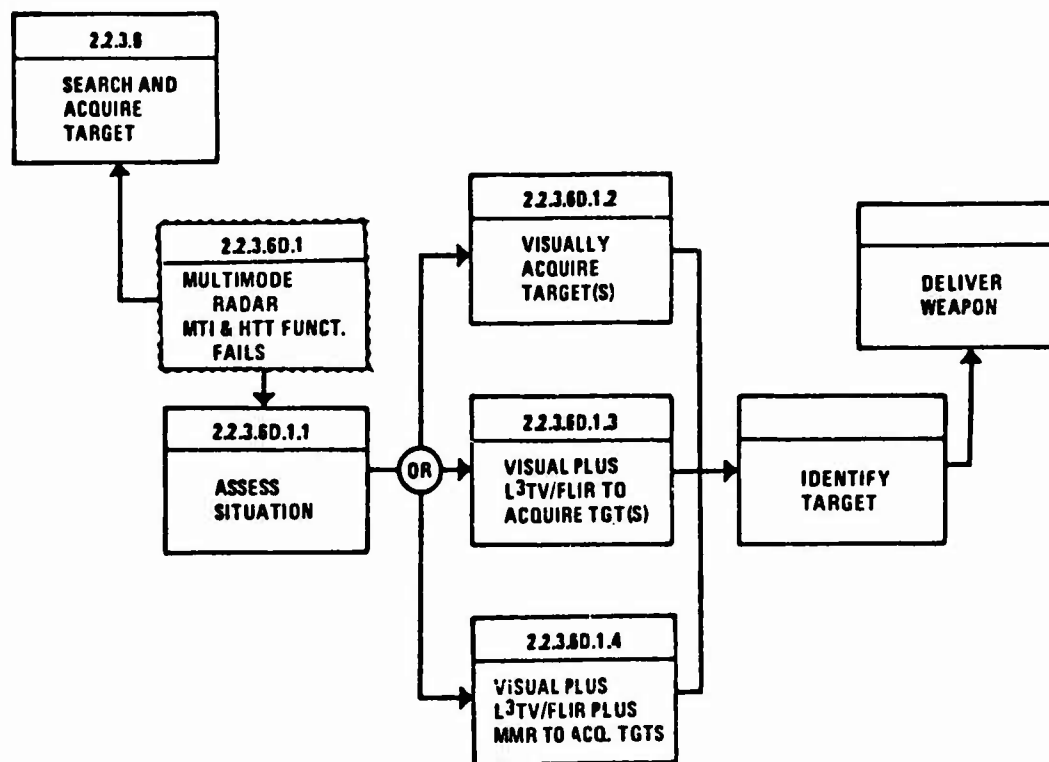


Figure 21. Multimode Radar MTI/HTT Mode Function Failure

Degraded Mode: MULTIMODE RADAR MT(1) AND HTT(2) FUNCTIONS FAIL -- A/G COM:AT

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), L3TV & 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 "FC3"--ATA • Target Selection (truck, tanks, train, 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 "4" in storage. 4. Radio modes (voice, voice and D/L) available.	Master Caution, Voice, HUD/VSD MPD MPD	Comm./Ident. Panel & Microphone 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) • Blk & Symbols on HUD/VSD • Voice Warning
2.2.3.6D.1.1 Assess Situation		1. Consider: Fault Reminiscing 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/BSO MPD HSD (Map) HSD/BSO MPD	TNC TNC TNC TNC TNC TNC TNC	2.0 2.0 2.0 2.0 2.0 2.0 (3) above	Monitor & Control A/C & Monitor Enemy Activity " " " " " " "	6.0 6.0 6.0 6.0 6.0 6.0 6.0	Man Man Man Man Man Man 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.1.2 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	Man/Machine Man/Machine Man	Require means to select individual sensors. Require means to adjust dis- play intensity and contrast.	See revised sensor/ display select panel • FLIR • L3TV See level control panel • Intensity • Contrast • HUD/VSD/HSD/ MPD-1 through MPD-5
2.2.3.6D.1.3 Perform Visual Plus Acq. Target(s)		1. Descend to visual altitude. 2. Select MMR "Beacon". 3. Deactivate ATA mode. 4. Select EO(S) 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. L3TV/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	5.0 1.5 3.0 3.0 3.0	" " " " "	5.0 5.0 5.0 5.0 5.0	Man/Machine Man Man Man Man Man/Machine		
		(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	IN-O AVAIL/ WHERE	CONTROL AVAIL/ WHERE	TASK TIME AVAIL	TASK TIME RECD	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	2.2.3.8D.1.3 (continued)	7. Select E-O to bore-sight 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) avail- able, target-sensor matching	HUD/VSD/HSD HUD/VSD/HSD HUD/VSD/HSD	No No Designation Control	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 Bore-sight/ Individual See revised Radar Mode Select Panel. o TV/FLIR MTI Require: MMR "Spotlight" function Require: Search area for "Spotlight" mode.	See trade sheet. E-O Auxiliary Control Panel o Stow o Bore-sight/ Individual See revised Radar Mode Select Panel. o TV/FLIR MTI Require: MMR "Spotlight" function Require: Search area for "Spotlight" mode. Select Panel. o Add "Spotlight" mode Keyboard "ECS-MMR" o Add 1 x 1.2 x 2 or 4 x 4 nm search area See new Desig. Control o Enable o Range, az. & elev. o Lock on/reject
	2.2.3.8D.1.4	1 thru 11. Same as above	See 1-11 above.		No	30.0	2.0	" " "	6.0	Man		
	Perform Visual	12. Select MMR High res. GM(2) mode	12. MMR "Spotlight" mode avail.		No	30.0	2.0	" " "	6.0	Man		
	Plus L3TV/FLIR	13. Select MMR HRGM(3) search area.	13. 1 x 1.2 x 2 or 4 x 4 nm			30.0	3.0	" " "	6.0	Man		
	Plus MMR to Acq.	14. Monitor radar display	14. HRGM details	HSD		30.0	5.0	" " "	6.0	Man		
	Target(s)	15. Monitor moving map display.	15. Topographical & cultural detail	HSD/Map		30.0		" " "				
		16. Monitor E-O display.	16. Video & contrast levels	HUD/VSD		30.0	5.0	" " "	6.0	Man		
		17. Correlate position & threat data from all displays.	17. Target-sensor matching, MTI video & detailed maps of area	HUD/VSD/HSD		30.0	Included in 1 above	" " "	6.0	Man		
		18. Locate threat(s).	18. Symbology	HUD/VSD/HSD		30.0	above	" " "	6.0	Man/Machine		
		19. Designate threat.	19. Grapher position control in 360° az.	HUD/VSD/HSD	Designation Controller	30.0	5.0	" " "	6.0	Man/Machine	Require means to designate targets.	

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

Degraded Mode: MULTIMODE RADAR FAILE IN MT1 & HTT MORNES :A/G COMBAT

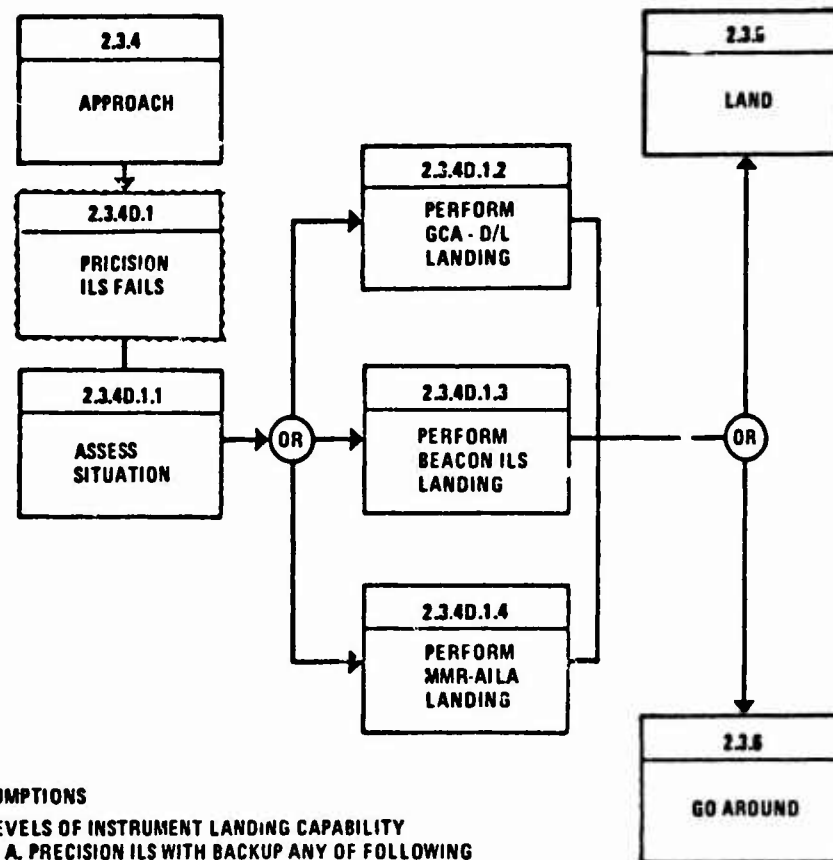
DESIGN TRADE STUDY

DISPLAY/CONTROL REQUIREMENTS		OPTION NO. 1	OPTION NO. 2	OPTION NO. 3	SELECTION	
E-O Stow/Boreight/Individual Slave		Illuminated push buttons.	Three position toggle switch.	Keyboard/voice control.		
CRITICALITY Low since normal switch position is boreight.						
FREQUENCY OF USE Medium to low		Pro: 1. Simple motion. 2. Good space factor. 3. Several modes compatible with single push button. 4. Suitable for D/L and digital equipment. 5. Good indication of status. 6. Ease of operation with gloved hand.	Pro: 1. Simple motion. 2. Good feel associated with switch position. 3. Does not require visual coordination for operation. 4. Good space factor.	Pro: 1. Multiple use. 2. Compatible with digital equipment. 3. Makes use of space already available.	Option 1 Illuminated push buttons indicating "Stow", "Boreight", or "Individual Slave". Normal switch position is "Boreight" which keeps E-O sensors line-of-sight aligned with radar crosshair.	
RESPONSE TIME						
PRECISION REQUIREMENTS None		Con: 1. Must be looked at to operate. 2. Increases	Con: 1. Cannot program switch functions with digital equipment or D/L.	Con: 1. Takes too long to perform single function when change or modification is needed. 2. Complex.		
ENVIRONMENT CONSTRAINTS None		2. Increases ambient light in cockpit.				
LOCATION ALLOCATION						
VISION Primary						
REACH Secondary						

Degraded Mode: MULTIMODE RADAR FAILS IN MTI & HTT MODES - A/G COMBAT

DESIGN TRADE STUDY

DISPLAY CONTROL REQUIREMENTS Warning Device (Mission Critical)	OPTION NO. 1 Warning light and prinitout on MPD	OPTION NO. 2 Warning light, blink primary symbols on HUD/VSD and voice warning.	OPTION NO. 3 Warning light, blink primary symbol on HUD/VSD, voice and tactile warning.	SELECTION	REMARKS
CRITICALITY Relatively high - requires positive warning but response time not in flight safety category. FREQUENCY OF USE Medium RESPONSE TIME Medium to high. Remain on until acknowledged. PRECISION REQUIREMENTS High - no false alarms. ENVIRONMENT CONSTRAINTS Must be seen and felt in all ambient conditions. LOCATION ALLOCATION VISION Primary REACH Primary (Master Caution Lile)	Pro: - Simple. - Provides minimum action. Con: - Low attention. - Visual, cue only provides - Dependent on other systems	Pro: - Provides visual and auditory warning in primary viewing area. - Provides recommended action. - Provides necessary redundancy. Con: - Dependent on other systems.	Pro - Multiple warning with visual, auditory and tactile - Provides recommended action - Provides necessary redundancy. Con: - Permits high stimuli even though "Flight Safety" is not involved. - Dependent on other systems.	Option 2 Provides necessary warning to crew on "Mission Critical," or lesser system failures	Recommend following action: - Warning light would be similar to a "Master Caution" located in primer, viewing area - In addition, the HUD/VSD aircraft symbology and/or items symbol would blink. - Voice warning. - FMAC/CCC would provide instructions on a MPD. Note: Tactile warning would be required for safety if flight failure occur.



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/terminal controller.	1. Fault exists 2. Visual cue/entry. 3. Stored logic procedure. 4. Preprogrammed msg. to crew. 5. Radio comm. available (position, voice).	Master Caution, Voice, HUD/VSD MPD MPD	(Storage) 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 Machine 2.0 Men/Machine 2.0 Machine 2.0 Men 2.0 Men/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	2.0 1.0 2.0 1.0 2.0 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/telemetry. 4. Engage autopilot and continue approach.	1. GCA D/L available. 2. Pitch and roll commands (item). 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	3.0 2.0 3.0 1.5 (Allow 3.0 sec if manual)	" " " "	3.0 Men/Machine 3.0 Men 3.0 Men 3.0 Men	Requires means to select any alternate landing system. Requires means to engage autopilot in pitch and roll axis during land.	Use keyboard com. 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 concent reasons.									

Degraded Mode: PRECISION ILS FAILURE - APPROACH

[illegible]

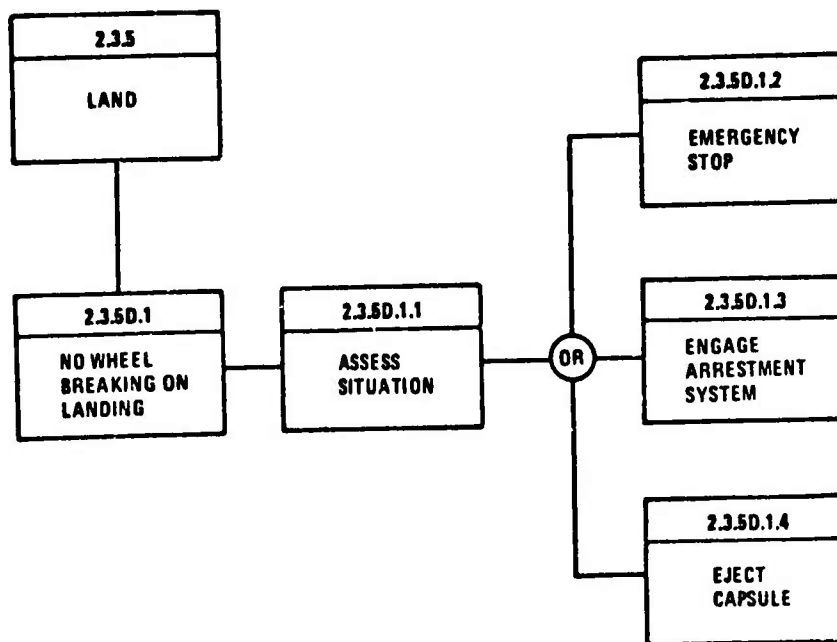


Figure 23. Brake Failure

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 Preprogrammed instructions to crew 4. Radio voice available (voice)	Meter Caution; Voice HUD/VSD MPD MPD	(Storage) Comm/Ident. Panel Microphone	1.0 2.0 3.0	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 effect 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 Prelearned 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			Var. 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 & Rudder	2.0	1.5	"	2.0 2.0	Man/Machine Man/Machine	Require: Ground track steering symbology—actual and command	HUD/VSD May be included with item 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

[illegible]

Summary Normal LL Pen.

PILOT WORKLOAD DATA

[illegible]

SOURCE OF FUNCTION	FUNCTION & CORRESPONDING TASKS (IF APPLICABLE)	TIME (MINUTES)					
		1	2	3	4	5	6
1	Monitor Flight (VSD) Terrain Clearance Energy Control Director A/C Symbol Following Absolute Altitude EAS						
2	Monitor Terrain Avoidance (MPD 3)						
3	Monitor Navigation (HSD) Check Points Turn Points Target Present Position ETA ETE						
4	Ground Track Compare With PP Route Monitor Communications (Audio)						
5	Monitor Battle Situation (MPD 4) 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.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	LFT	HAND	FEET	COGN	AUDIT	VERE	TOTAL	TOTAL	TOTAL
(1)	VIS	INT	LFT	HAND	FEET	COGN	AUDIT	VERE	TOTAL	TOTAL	AVE
1	11.3	100.2	0.0	0.0	0.0	56.0	40.0	0.0	111.5	0.0	20.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
3	10.9	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0
4	9.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0
5	10.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0
6	10.9	98.2	0.0	0.0	0.0	54.6	40.0	0.0	109.2	0.0	20.0
7	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0
8	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0

CAPTAIN WORKLOADING SUMMARY
AVERAGE AND STANDARD DEVIATION
WORKLOADING PER UNIT TIME

IIPACS NORMAL LOW LEVEL PENETRATION						
CHANNEL	N	SLM X	SLM X SG	AVERAGE	S	S SQ FE
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

[illegible]

REPRESENTATIVE MISSION REQUIREMENTS

[illegible]

Summary - Engine Failure

PILOT WORKLOADING DATA

[illegible]

CAPTAIN WORKLOADING SUMMARY											
FAILURES LOW LEVEL PENETRATION - ENGINE MALFUNCTION											
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	IFT	HAND	FEET	CCGN	AUDIT	VEFB	TOTAL	TOTAL	TOTAL
(1)	VIS	INT	IFT	HAND	FEET	CCGN	AUDIT	VEFB	TOTAL	TOTAL	TOTAL
1	9.4	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0
2	8.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0
3	2.4	75.6	15.2	8.4	0.0	68.2	43.4	0.0	78.0	7.9	21.7
4	6.6	88.7	0.0	0.0	0.0	37.2	40.0	0.0	65.3	0.0	20.0
5	10.3	81.7	0.0	0.0	0.0	47.0	40.0	0.0	92.0	0.0	20.0
6	11.4	94.2	0.0	0.0	0.0	53.0	40.0	0.0	106.0	0.0	20.0
7	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
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
											17.9
											25.4
											15.0
											18.8
											21.0
											19.9
											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	10.753	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	20424.614	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	169.523
10	8	7.86	61.710	.982	2.777	7.714
11	8	161.70	3270.843	20.212	.601	.361
12	8	154.97	3141.110	19.622	2.951	8.710

REPRESENTATIVE MISSION REQUIREMENTS

[illegible]

Summary Auto Terrain Follow Fail

PILOT WORKLOADING DATA

[illegible]

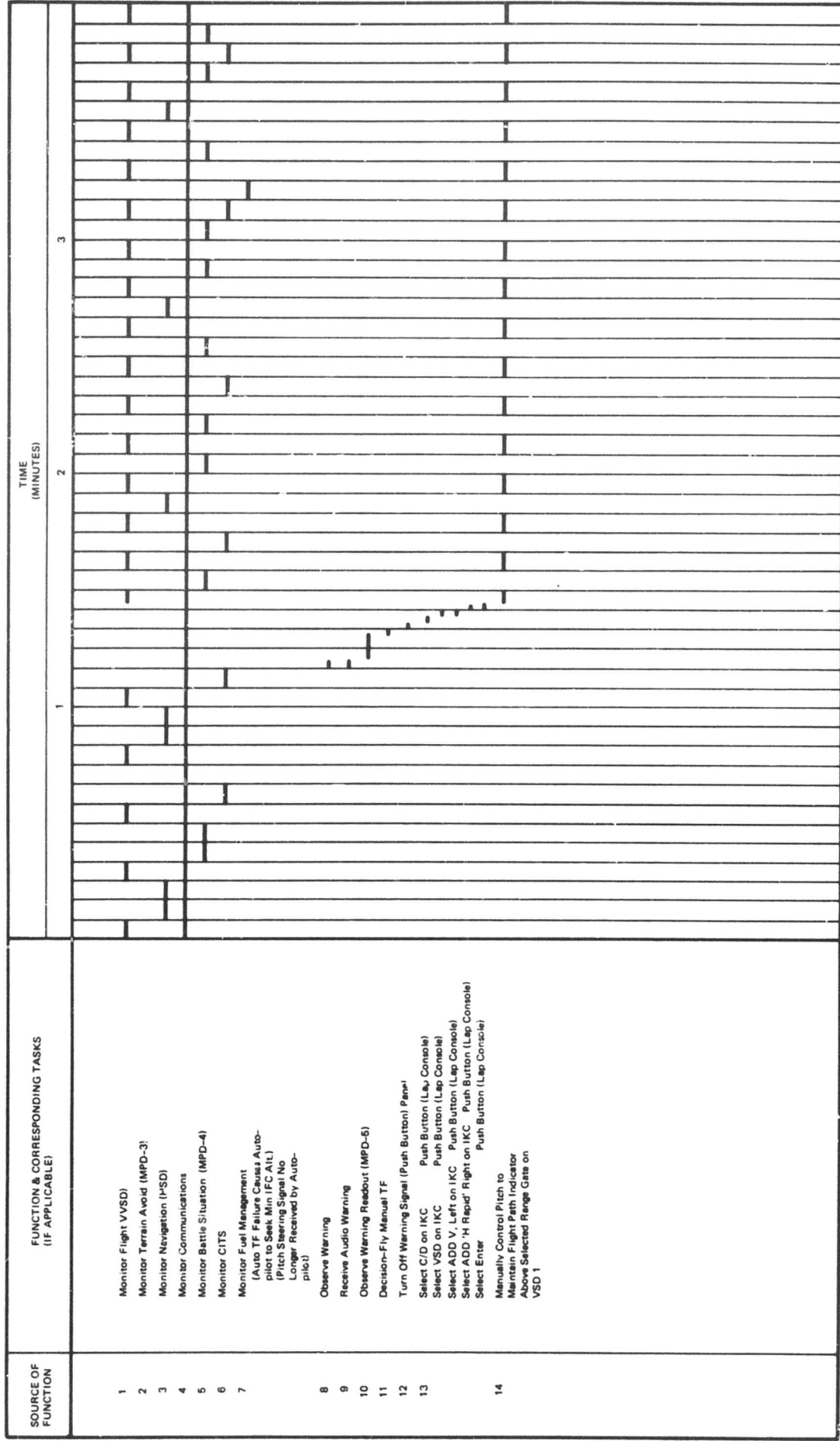


Figure 26. Low Level Penetration (TF/TA)
(Auto Terrain Following Failure)

CAPTAIN WORKLOADING SUMMARY											
FAILURES LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE											
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	TNT	LFT	HAND	FEET	CCGN	AUDIT	VERB	TOTAL VIS	TOTAL MOTOR	TOTAL COMB
(1)	VIS	VIS	LFT	HAND	FEET	CCGN	AUDIT	VERB	TOTAL VIS	TOTAL MOTOR	TOTAL COMB
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	75.4	0.0	20.0
2	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0
3	2.4	65.2	16.8	21.4	0.0	58.7	46.7	0.0	67.6	12.7	23.4
4	13.7	98.9	0.0	64.3	0.0	81.0	40.0	0.0	112.6	21.4	20.0
5	13.6	86.4	0.0	85.7	0.0	83.5	40.0	0.0	100.0	28.6	20.0
6	11.3	87.5	0.0	85.7	0.0	84.5	40.0	0.0	98.8	28.6	20.0
7	12.2	86.4	0.0	85.7	0.0	83.5	40.0	0.0	98.6	28.6	20.0
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	545.30	42636.018	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	3898.558	18.561	12.719	161.778
11	8	163.37	3345.984	20.421	1.150	1.417
12	8	252.09	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

[illegible]

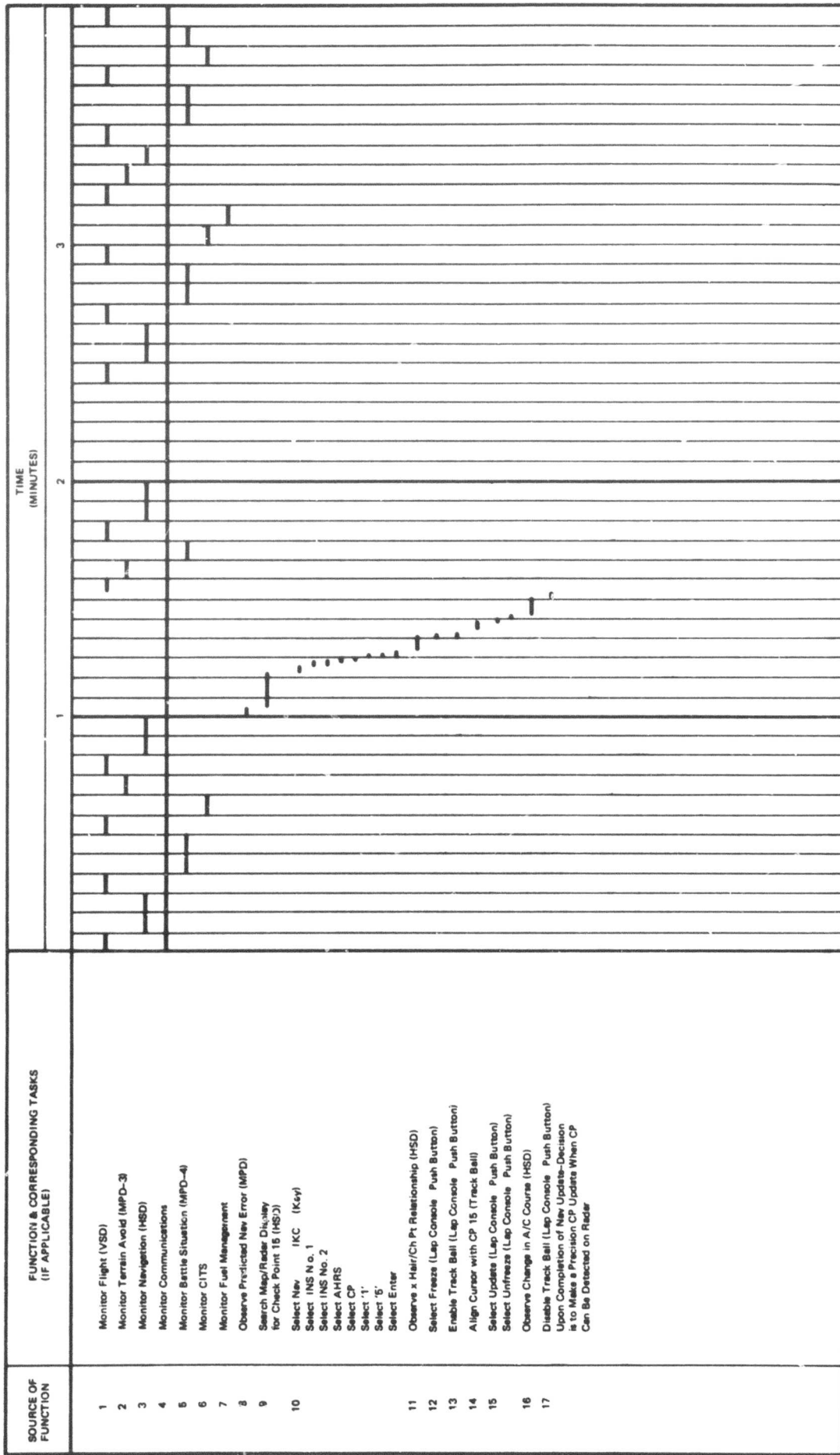


Figure 27. Low Level Penetration (T/F/A)
(Navigation Satellite Failure)

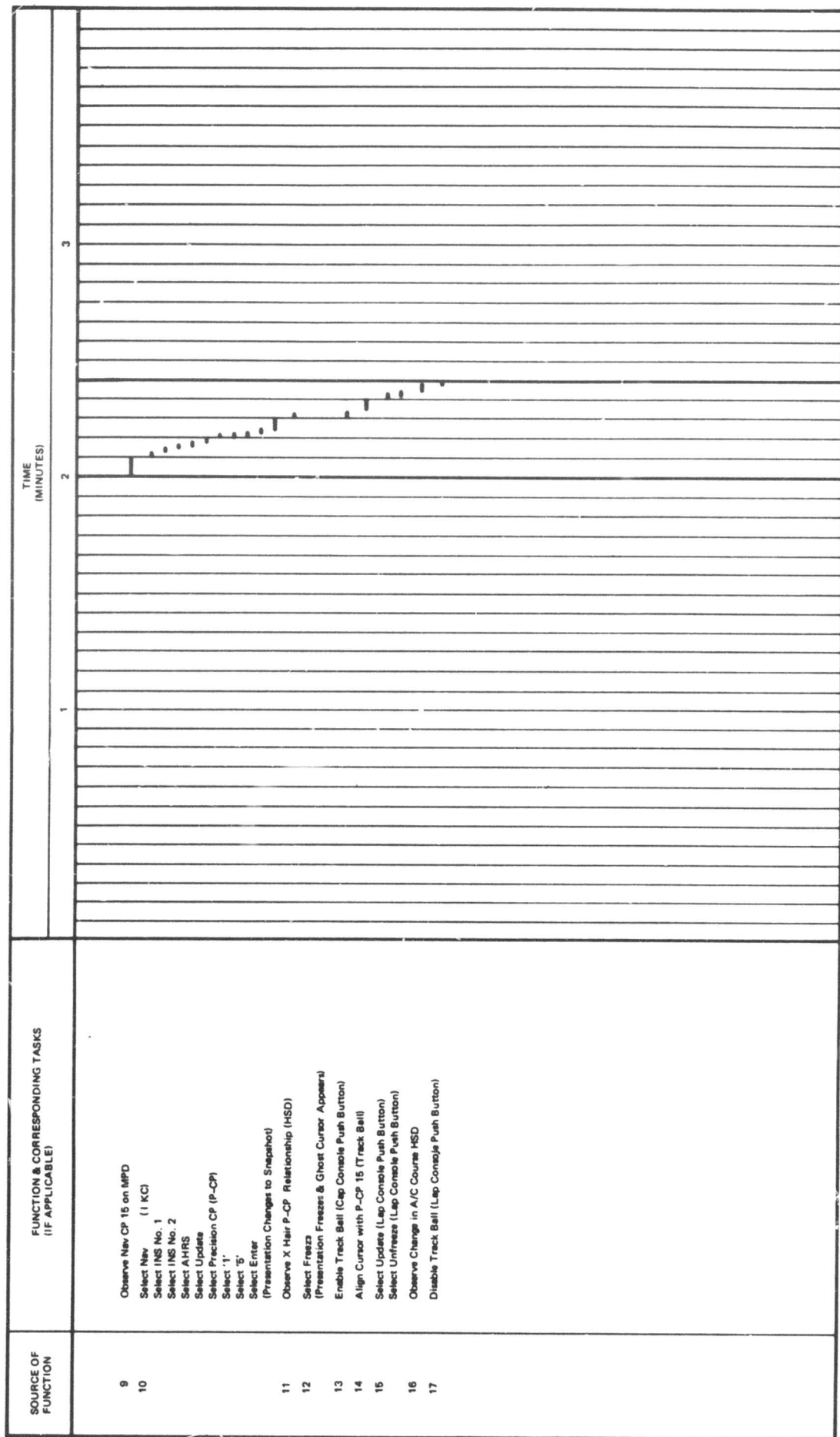


Figure 2). Low Level Penetration (V/F/A)
Navigation Satellite Failure) (Continued)

CAPTAIN WORKLOADING SUMMARY											
FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE											
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	LEFT	RIGHT	FEET	CCGN	AUDIT	VERB	TOTAL	TOTAL	TOTAL
(1)	VIS	VIS	HAND	HAND	FEET	CCGN	AUDIT	VERB	VIS	NOTOR	COMM
AVE											
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
2	11.0	77.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
3	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0
4	5.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
5	2.5	99.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0
6	2.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
7	3.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0
8	11.7	69.0	0.0	0.0	0.0	41.3	40.0	0.0	80.7	0.0	20.0
											17.5
											16.5

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	647.03	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	9.925	98.705
7	8	320.00	12799.974	40.000	0.000	0.000
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	67.202
11	8	120.00	3199.994	20.000	0.000	0.000
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 Distribution Fail

PILOT WORKLOADING DATA

[illegible]

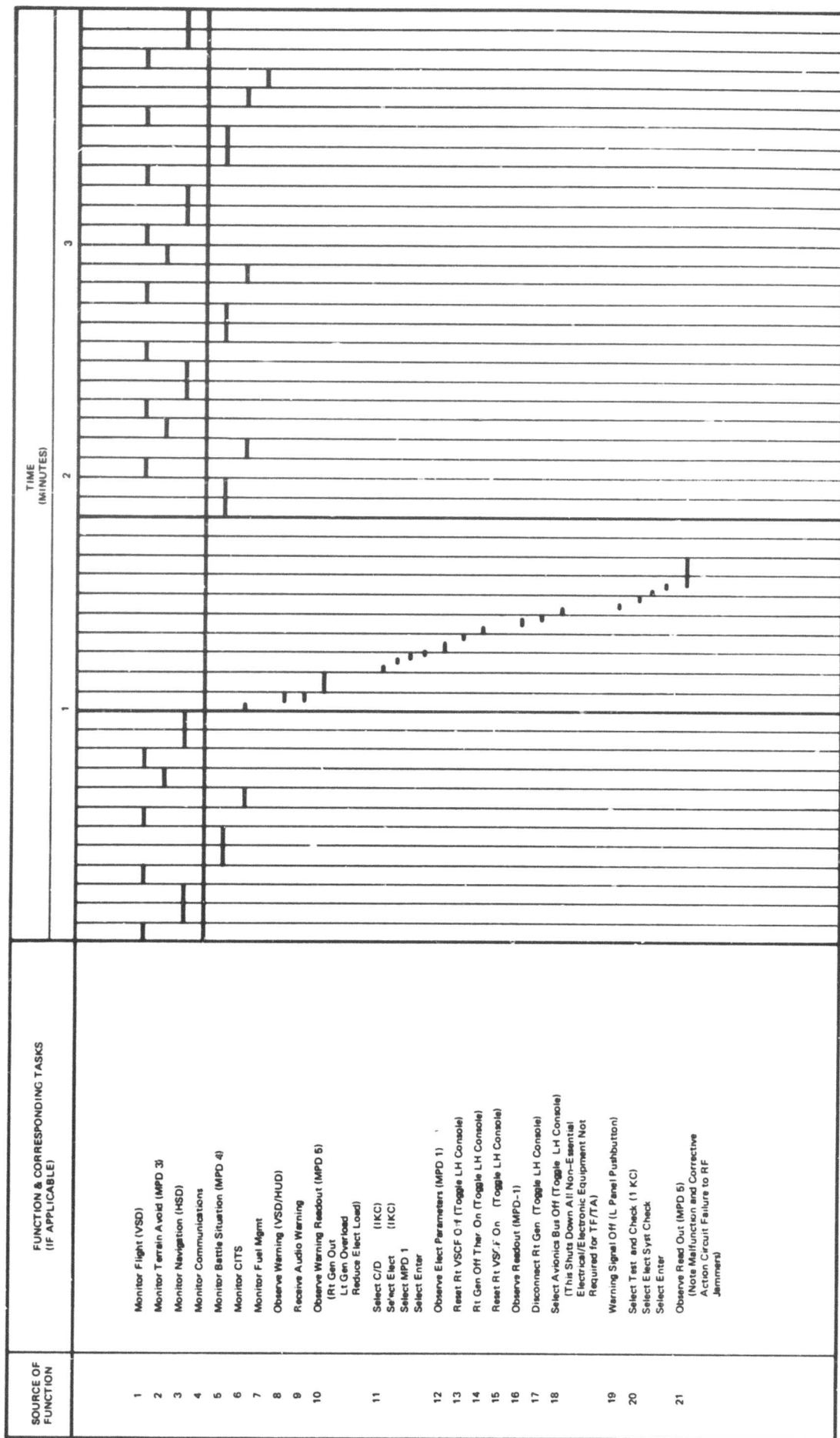


Figure 28. Low Level Penetration (TF/TA)
(Elect. Distribution Failure)

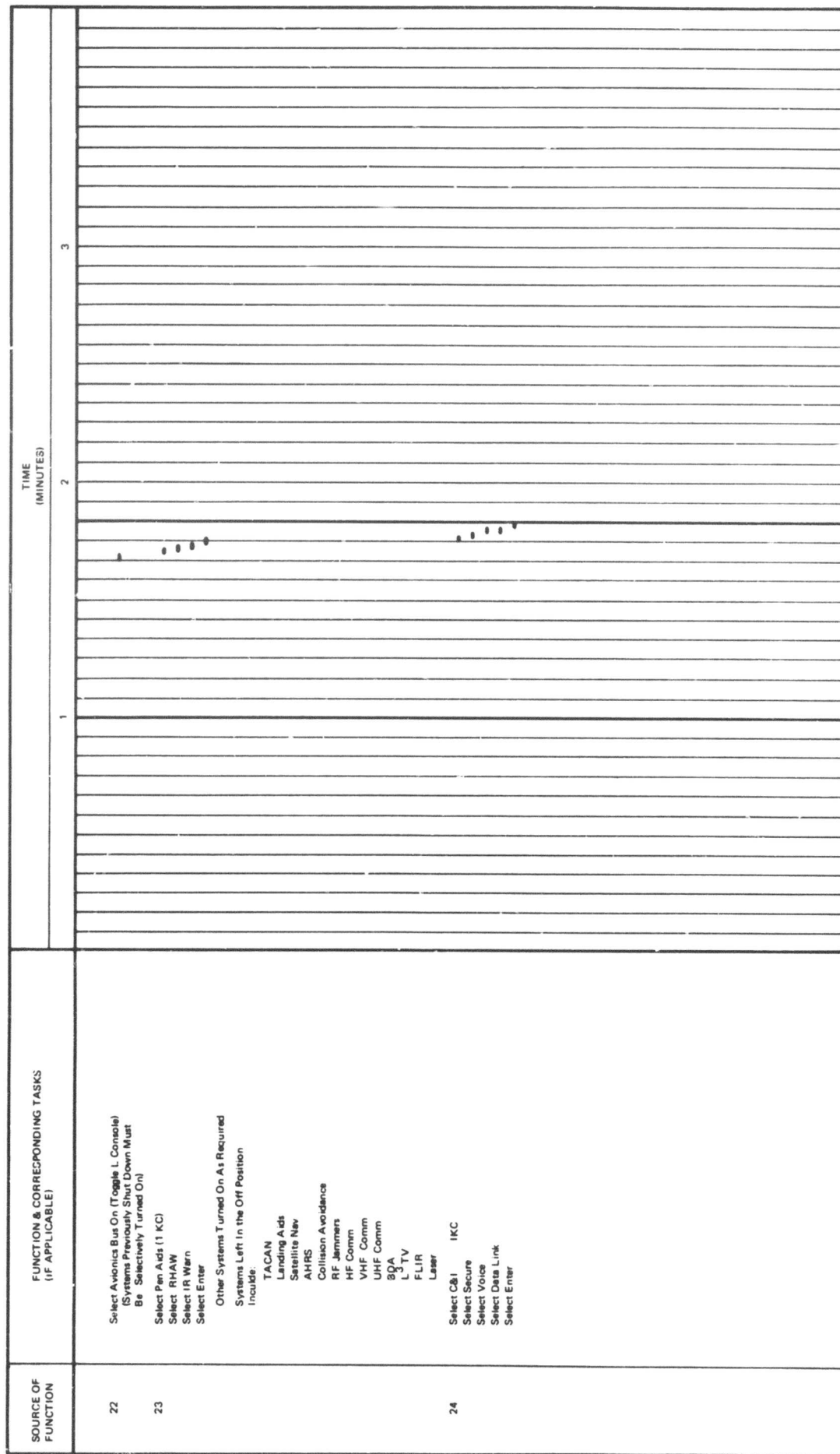


Figure 28. Low Level Penetration (TF/TA)
(Elect. Distribution Failure) (Continued)

CAPTAIN WORKLOADING SUMMARY											
FAILURES LOW LEVEL PENETRATION - ELECT. DIST. FAILURE											
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	IFT	HAND	FEET	COGN	AUDIT	VERB	TOTAL	TOTAL	TOTAL
(1)	VIS	INT	IFT	HAND	FEET	COGN	AUDIT	VERB	VIS	MOTOR	COMM
AVE											
1	9.3	82.8	0.0	0.0	0.0	47.5	40.0	0.0	92.2	0.0	20.0
2	11.0	97.8	0.0	0.0	0.0	55.0	40.0	0.0	108.8	0.0	20.0
3	2.4	91.3	10.2	25.2	0.0	80.9	46.7	0.0	93.7	11.8	23.4
4	2.7	52.6	2.4	16.8	0.0	48.5	40.0	0.0	55.3	6.4	20.0
5	11.0	98.0	0.0	0.0	0.0	55.0	40.0	0.0	109.0	0.0	20.0
6	12.8	85.5	0.0	0.0	0.0	49.0	40.0	0.0	98.3	0.0	20.0
7	9.3	82.8	0.0	0.0	0.0	47.5	40.0	0.0	92.2	0.0	20.0
8	11.3	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

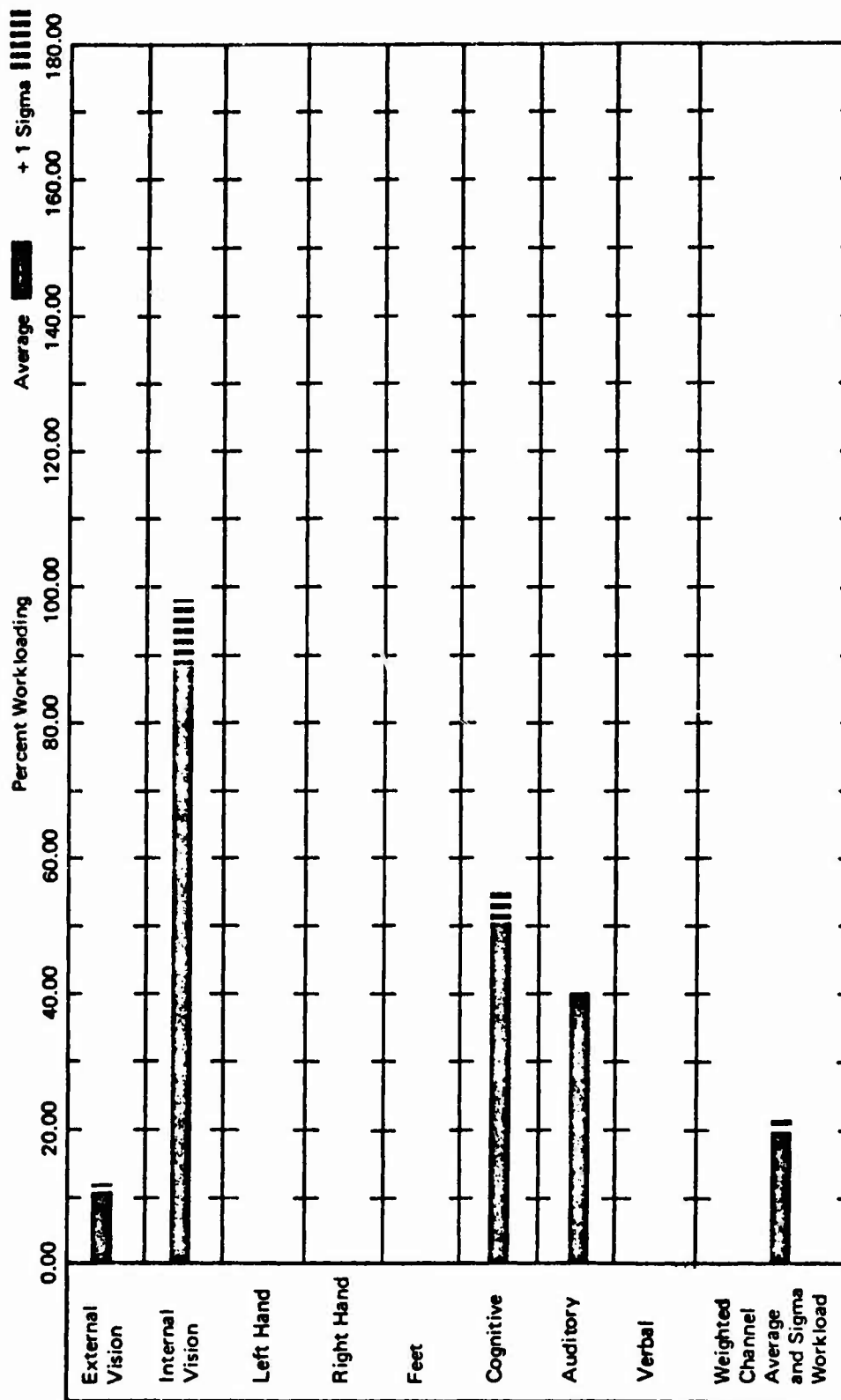
FAILURES LOW LFVEL PENETRATION - ELECT. DIST. FAILURE						
CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	68.90	700.584	8.612	3.913	15.312
2	8	682.83	5764.637	85.354	14.551	211.726
3	8	12.53	108.942	1.567	3.572	12.761
4	8	42.00	917.278	5.250	9.977	95.540
5	8	0.00	0.000	0.000	0.000	0.000
6	8	426.13	24631.000	54.517	11.049	122.073
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	751.73	72677.028	93.967	17.069	291.236
10	8	18.18	179.795	2.272	4.448	19.785
11	8	162.37	3345.954	20.421	1.190	1.417
12	8	171.05	3796.476	21.456	4.027	16.217

APPENDIX III
COMPUTER WORKLOAD ANALYSIS SUMMARY

CAPTAIN WORKLOADING SUMMARY											
IIPACS						NORMAL LOW LEVEL PENETRATION					
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	LFT	HAND	FEET	COGN	AUDIT	VERB	ICTAL	TOTAL	TOTAL
VEH	VIS	VIS	VIS	RT	FEET	COGN	AUDIT	VERB	VIS	TOTAL	VEH
AVE											
1	11.3	100.2	0.0	0.0	0.0	56.0	40.0	0.0	111.5	0.0	20.0
2	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
3	10.4	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0
4	9.3	82.2	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0
5	10.3	92.0	0.0	0.0	0.0	52.0	40.0	0.0	102.3	0.0	20.0
6	10.4	98.2	0.0	0.0	0.0	54.6	40.0	0.0	105.2	0.0	20.0
7	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	75.2	0.0	20.0
8	11.0	87.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
											19.5

CAPTAIN WORKLOADING SUMMARY											
IIPACS						NORMAL LOW LEVEL PENETRATION					
CHANNEL	N	SUM X	SUM X SG	AVERAGE	S	S SQUARE					
1	8	83.87	884.105	10.483	.837	.701					
2	8	86.13	62945.392	88.267	9.352	86.212					
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	75723.231	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					

Reproduced from
best available copy.



Oct 29, 1970
Date

Captain
Crew Member

Figure 29. IIPACS Normal Low Level Penetration

CAPTAIN WORKLOADING SUMMARY

FAILUREES LOW LEVEL PENETRATION - ENGINE MALFUNCTION

NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
EXT	VIS	INT	IFT	HAND	FEET	COGN	AUDIT	VERB	TOTAL	TOTAL	TOTAL	AVE
1	9.3	52.2	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	64.2	43.4	0.0	78.0	7.9	21.7	25.4
4	8.6	52.7	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	18.2
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	19.5
8	10.9	87.7	0.0	0.0	0.0	50.0	40.0	0.0	98.7	0.0	20.0	19.5

CAPTAIN WORKLOADING SUMMARY

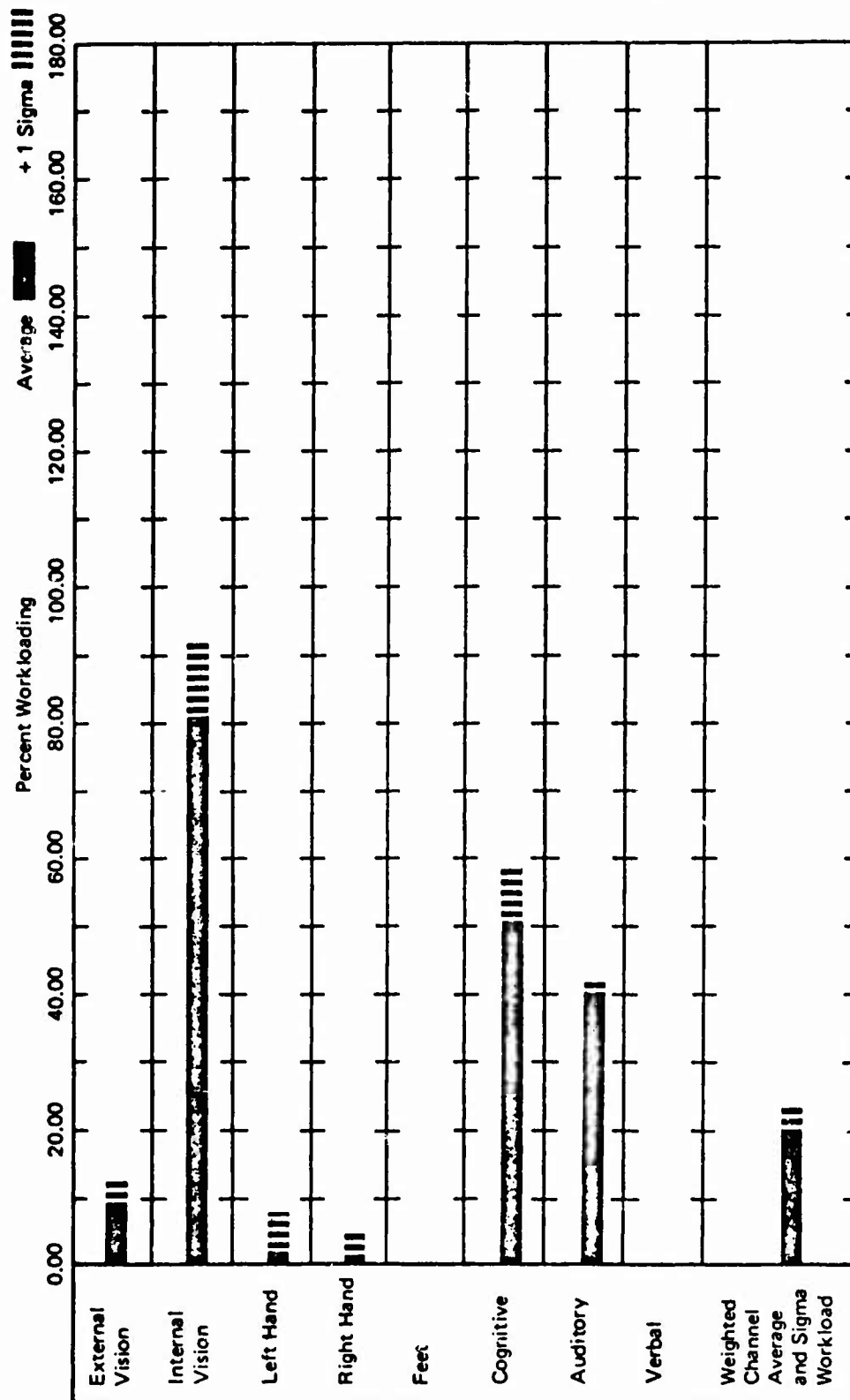
AVERAGE AND STANDARD DEVIATION

WORKLOADING PER UNIT TIME

Reproduced from
best available copy.

FAILUREES 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	10.753	116.497
3	8	15.17	230.027	1.896	5.362	28.753
4	8	8.40	70.560	1.050	2.470	8.820
5	8	0.00	0.000	0.000	0.000	0.000
6	8	398.90	20424.614	49.862	8.771	76.529
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	169.523
10	8	7.86	61.710	.982	2.777	7.714
11	8	161.70	3270.843	20.212	.601	.361
12	8	156.97	3141.110	19.622	2.951	8.710



Oct 29, 1970
Date

Captain
Crew Member

Figure 30. IIPACS Low Level Penetration-Engine Malfunction

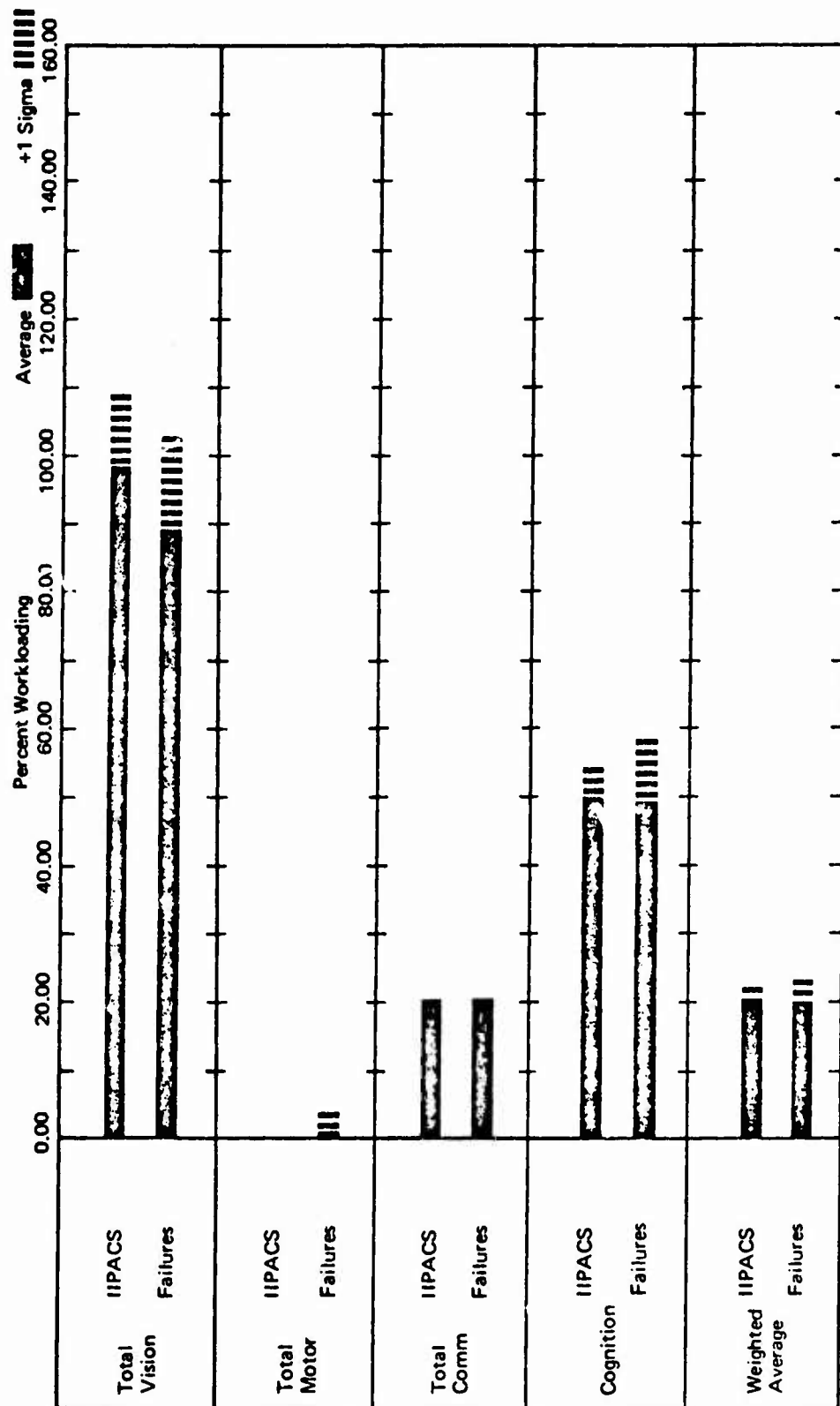


Figure 31. Normal Low Level Penetration-Engine Malfunction

Captain
Crew Member

Oct 29, 1970
Date

CAPTAIN WORKLOADING SUMMARY
LOW LEVEL PENETRATION - AUTO TERRAIN FOLLOWING FAILURE

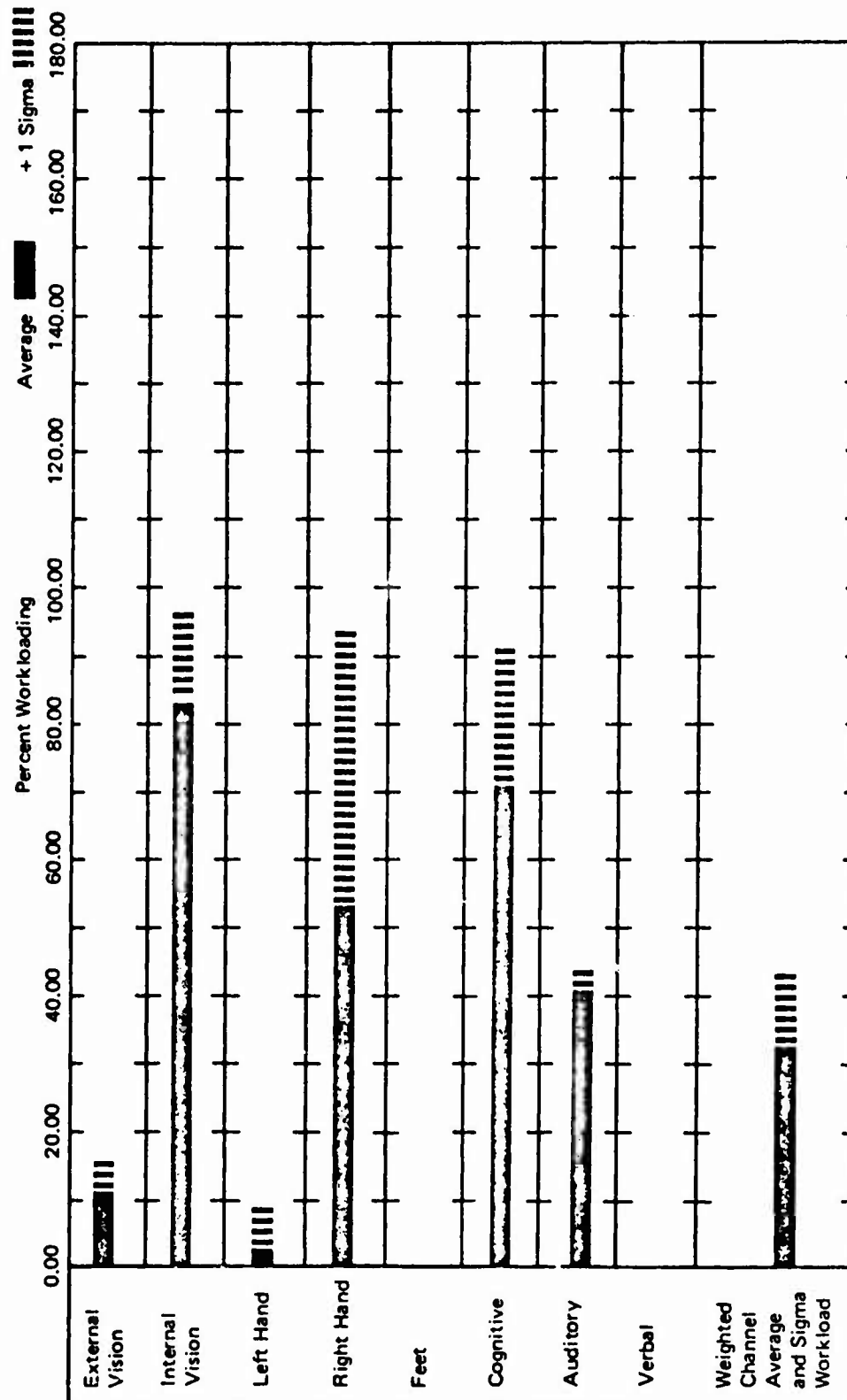
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
EXT	VIS	INT	HAND	RT	FEET	COGN	AUDIT	VERE	TOTAL VIS	TOTAL COMM	TOTAL	AVE
1	9.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0	17.0
2	9.1	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.2	0.0	20.0	17.0
3	2.4	65.2	16.8	21.4	0.0	58.7	46.7	0.0	67.6	12.7	23.4	25.7
4	13.7	48.5	0.0	64.3	0.0	81.0	40.0	0.0	112.6	21.4	20.0	36.5
5	13.6	46.4	0.0	65.7	0.0	83.5	40.0	0.0	100.0	28.6	20.0	39.5
6	11.3	47.5	0.0	65.7	0.0	84.5	40.0	0.0	98.8	28.6	20.0	39.5
7	12.2	46.4	0.0	65.7	0.0	83.5	40.0	0.0	98.6	28.6	20.0	39.5
8	12.1	48.5	0.0	65.7	0.0	83.5	40.0	0.0	112.6	28.6	20.0	41.5

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	3.810	14.577
2	8	63.50	5627.538	82.937	13.086	171.231
3	8	16.40	282.239	2.100	5.940	35.280
4	8	424.67	33994.628	53.583	29.687	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	748.43	71992.142	93.604	16.468	271.195
10	8	148.49	3898.559	18.561	12.719	161.778
11	8	163.37	3345.984	20.421	1.150	1.417
12	8	258.09	9124.678	32.261	10.679	114.040

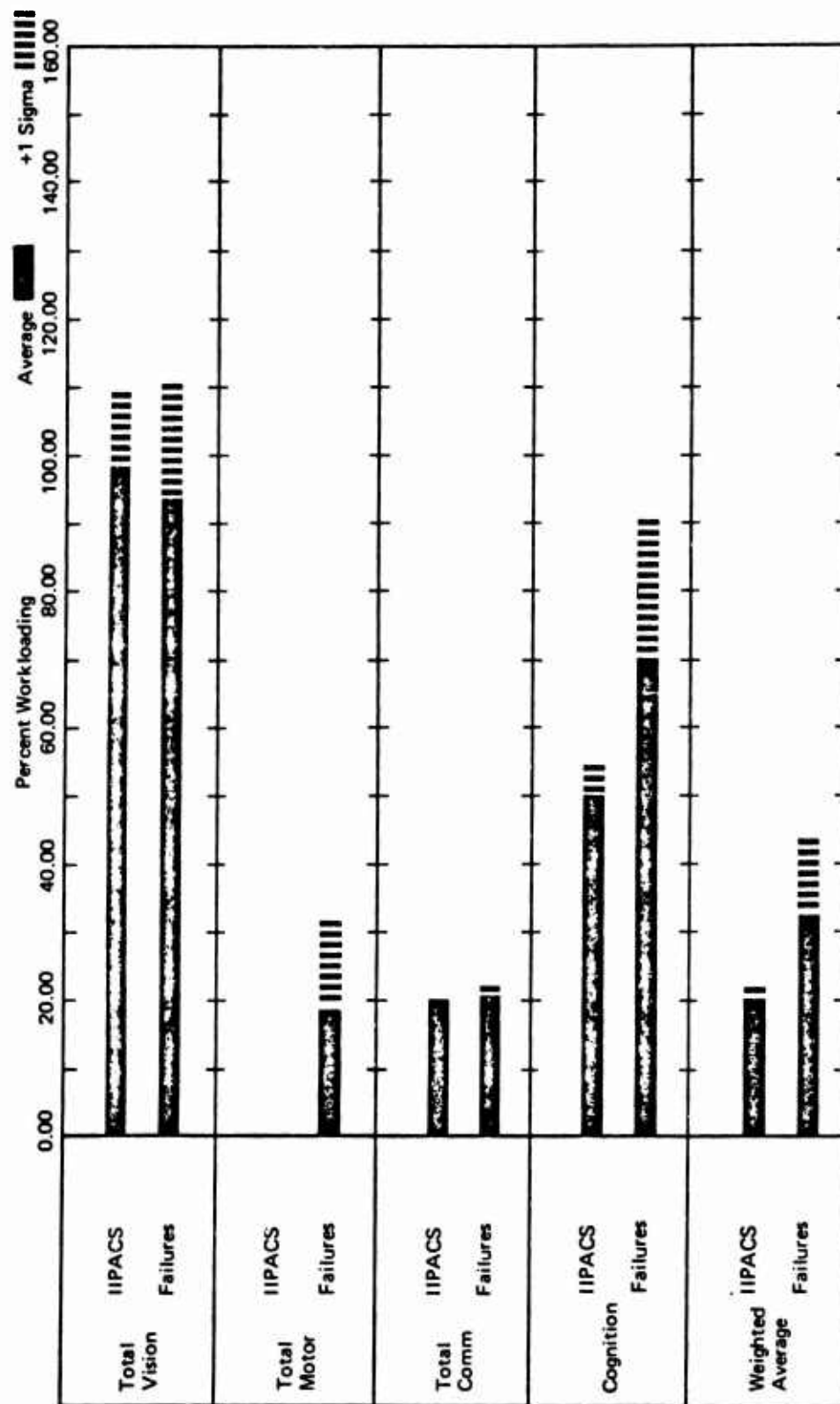
Reproduced from
best available copy.



Oct 29, 1970
Date

Captain
Crew Member

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



Oct 29, 1970
Date

Captain
Crew Member

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

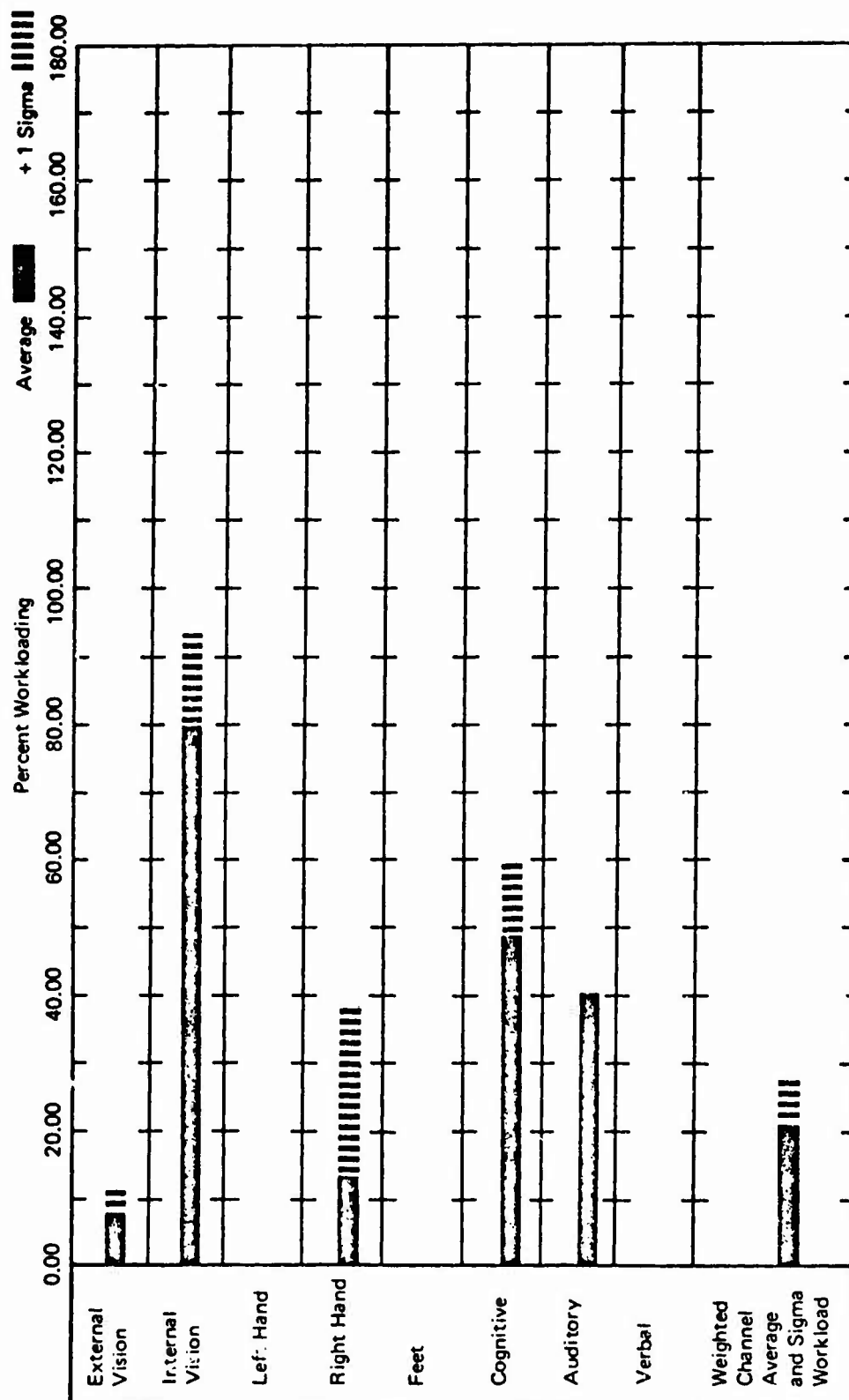
CAPTAIN WORKLOADING SUMMARY											
FAILURES LOW LEVEL PENETRATION - NAV. SAT. FAILURE											
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
EXT	VIS	INT	LEFT	HAND	FEET	COGN	AUDIT	VFRE	TOTAL	MOTOR	TOTAL
(1)	VIS	INT	LEFT	HAND	FEET	COGN	AUDIT	VFRE	TOTAL	MOTOR	TOTAL
1	9.4	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
2	11.0	47.5	0.0	0.0	0.0	50.3	40.0	0.0	98.5	0.0	20.0
3	2.5	95.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0
4	5.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
5	2.5	95.0	0.0	53.2	0.0	64.5	40.0	0.0	101.5	17.7	20.0
6	2.3	70.1	0.0	0.0	0.0	42.3	40.0	0.0	79.4	0.0	20.0
7	3.6	76.1	0.0	0.0	0.0	45.3	40.0	0.0	84.7	0.0	20.0
H	11.7	69.0	0.0	0.0	0.0	41.3	40.0	0.0	80.7	0.0	20.0
											17.5
											16.5
											31.4
											17.0
											31.4
											17.0

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	649.83	52539.187	80.104	13.125	172.267
3	8	0.00	0.000	0.000	0.000	0.000
4	8	106.33	5653.374	13.292	24.611	605.719
5	8	0.00	0.000	0.000	0.000	0.000
6	8	392.73	15970.813	49.092	9.925	98.705
7	8	320.00	12799.974	40.000	0.000	0.000
8	8	0.00	0.000	0.000	0.000	0.000
9	8	705.17	62916.522	88.146	10.414	108.445
10	8	35.44	628.153	4.431	8.204	67.302
11	8	179.00	3199.994	20.000	0.000	0.000
12	8	168.61	3845.018	21.076	6.452	41.633

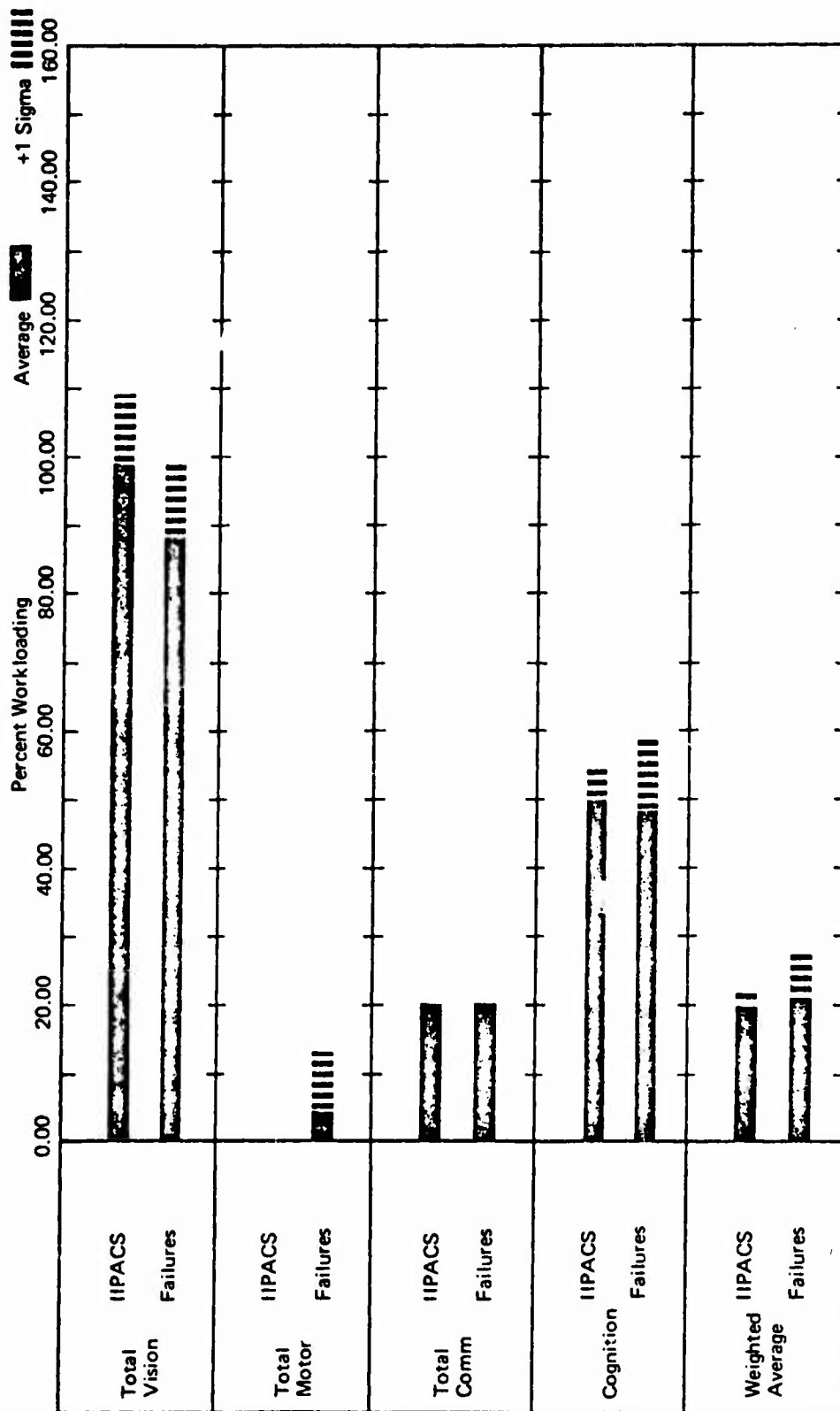
Reproduced from
best available copy.



Oct 29, 1970
Date

Captain
Crew Member

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



Oct 29, 1970
Date

Captain
Crew Member

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

CAPTAIN WORKLOADING SUMMARY
LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

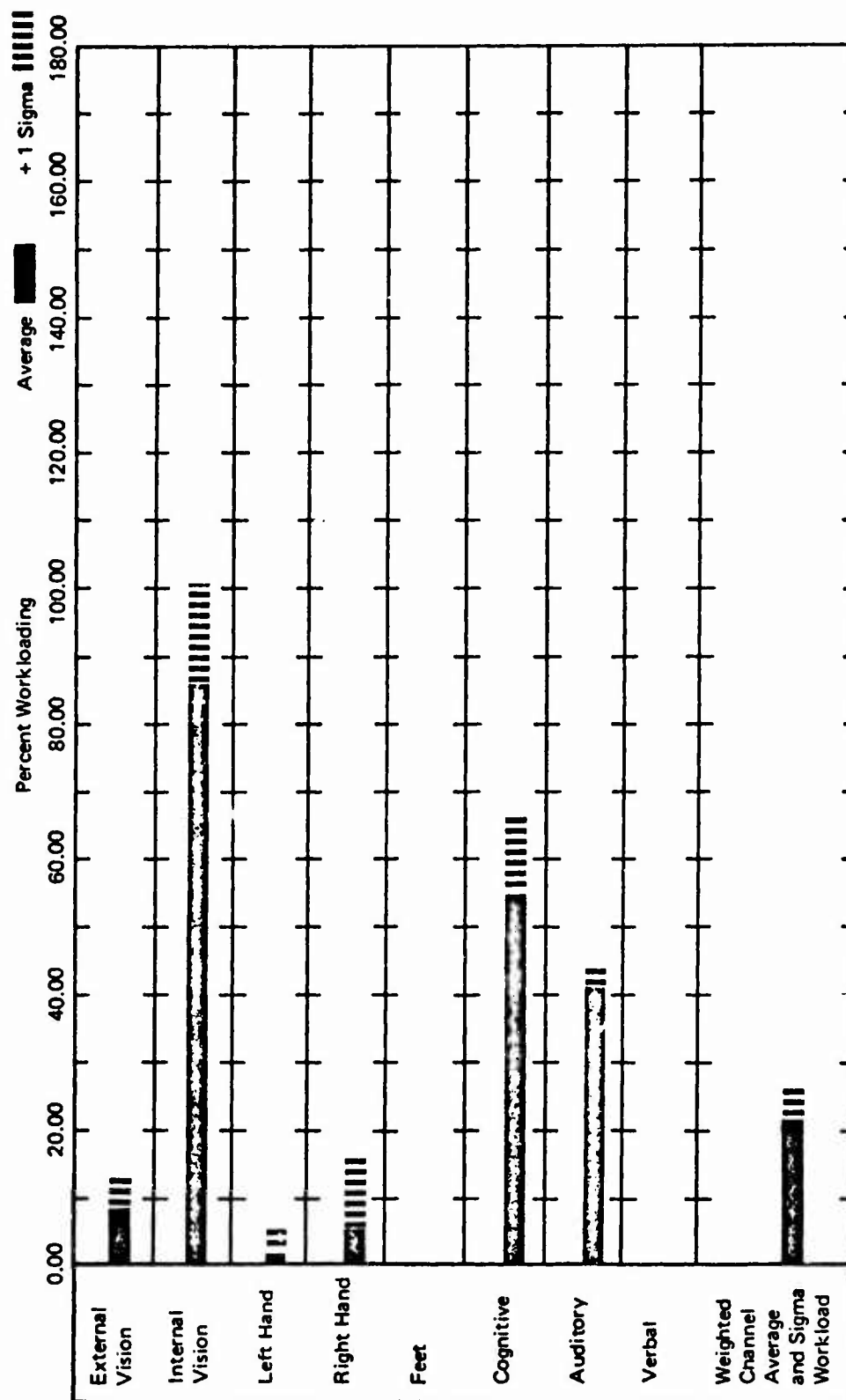
NO.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
EXT	VIS	INT	IFT	HAND	FEET	COGN	AUDIT	VERB	TOTAL	TOTAL	TOTAL	AVE
(1)	VIS	VIS	IFT	HAND	FEET	COGN	AUDIT	VERB	TOTAL	TOTAL	TOTAL	AVE
1	4.3	82.8	0.0	0.0	0.0	47.9	40.0	0.0	92.2	0.0	20.0	19.0
2	11.0	97.8	0.0	0.0	0.0	55.0	40.0	0.0	108.8	0.0	20.0	21.6
3	2.4	91.3	10.2	25.2	0.0	40.9	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	12.4	85.5	0.0	0.0	0.0	49.0	40.0	0.0	98.3	0.0	20.0	19.7
7	0.3	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

LOW LEVEL PENETRATION - ELECT. DIST. FAILURE

CHANNEL	N	SUM X	SUM X SQ	AVERAGE	S	S SQUARE
1	8	68.50	700.584	9.612	3.913	15.312
2	8	122.03	5764.637	15.254	14.551	211.726
3	8	12.53	108.942	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	72677.038	93.967	17.069	291.336
10	8	18.18	179.795	2.272	4.448	19.785
11	8	163.37	3345.934	20.421	1.150	1.417
12	8	171.05	3795.476	21.456	4.027	16.217

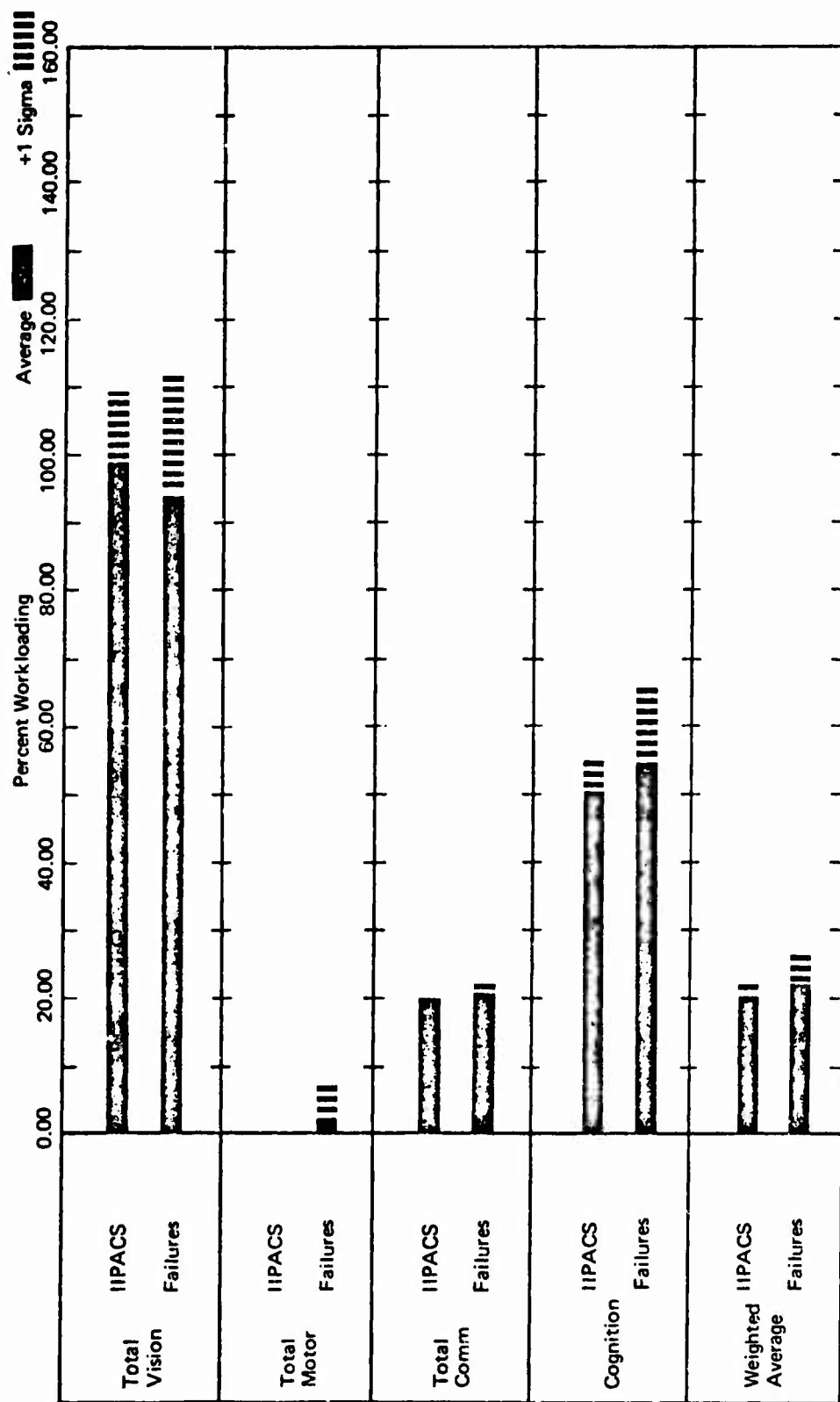
Reproduced from
best available copy.



Oct 29, 1970
Date

Captain
Crew Member

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



Oct 29, 1970
Date

Captain
Crew Member

Figure 37. Normal Low Level Penetration - Ext. Dist. Failure

REFERENCES

1. An Index of Electronic Equipment Operability - Data Store, American Institute for Research.
2. Dickey, L. R. Flight Deck Certification Computer Programs - Cockpit Crew Work Loading, D6-29906-3, The Boeing Company, December 1, 1969.