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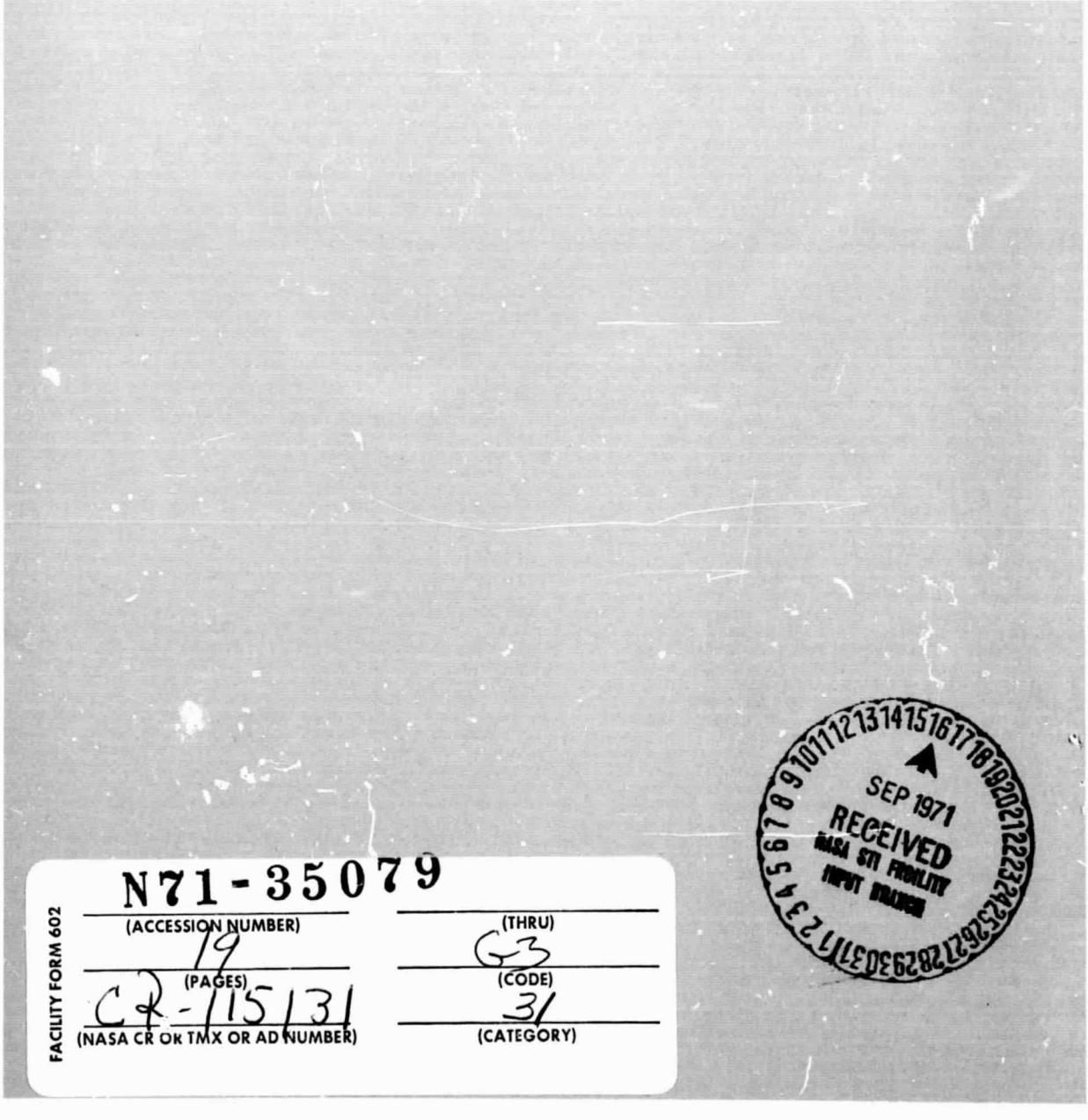
An Engineering Study of Onboard Checkout Techniques

FINAL REPORT

TASK 5: SUBSYSTEM LEVEL FAILURE MODES AND EFFECTS

Huntsville



IBM

An Engineering Study of Onboard Checkout Techniques

FINAL REPORT

TASK 5: SUBSYSTEM LEVEL FAILURE MODES AND EFFECTS

IBM NUMBER: 71W-00115

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Prepared for the
National Aeronautics and Space Administration
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Houston, Texas 77058

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FOREWORD

This is one of a set of five final reports, each one describing the results of a task performed under Contract NAS 9-11189, "An Engineering Study of Onboard Checkout Techniques." The five reports are as follows, all dated March 1971:

Task 1: REQUIREMENTS ANALYSIS AND CONCEPTS (IBM NO. 71W-00111)

Task 2: SOFTWARE (IBM NO. 71W-00112)

Task 3: ONBOARD MAINTENANCE (IBM NO. 71W-00113)

Task 4: SUMMARY AND RECOMMENDATIONS (IBM NO. 71W-00114)

Task 5: SUBSYSTEM LEVEL FAILURE MODES AND EFFECTS (IBM NO. 71W-00115)

The nine-month study was performed by the IBM Federal Systems Division at its Space Systems facility in Huntsville, Alabama, with the support of the McDonnell Douglas Astronautics Company Western Division, Huntington Beach, California.

Technical Monitor for the study was Mr. L. Marion Pringle, Jr., of the NASA Manned Spacecraft Center. The guidance and support given to the study by him and by other NASA personnel are gratefully acknowledged.

INTRODUCTION

A Failure Effects Analysis (FEA) was previously performed in support of Task 1. Its results appear in the Task 1 Final Report. This Task 5 Final Report contains an expansion of the FEA for the following subsystems:

- Guidance, Navigation, and Control (GN&C)
- Data Management
- Communications

The level of detail previously reported under Task 1 for other subsystems is considered sufficient for clear understanding. The procedure employed herein is similar to that of the earlier analysis, except that a distinction was made between "single" and "multiple" failures. The term "multiple failures" implies complete loss of the function under consideration. A description of the baseline subsystems is also contained in the Task 1 Final Report.

Generally, this FEA, coupled with other results, indicates that no failure modes exist which invalidate the onboard checkout concepts. It is worthy of note that the analysis was conducted at the component level, commensurate with available Space Station subsystem design definition. It is, therefore, recommended that a future effort be undertaken to expand the FEA to the signal level, with accompanying piece part level design data, for the purpose of eliminating, or insuring detection of, residual single-point failures.

The results of the FEA performed under Task 5 are tabulated in the remaining pages of this report.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: GN&C

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
GN&C Subsystem	Provides for Navigation, Guidance, and Attitude Control of Space Station. Accomplishes spin control and wobble damping in the artificial-g mode. Earth-centered and inertial attitude control is available in zero-g mode. Provides automatic rendezvous and docking with approaching vehicles.			
Attitude Gyro Assembly	Provides inertial attitude/ attitude rate information required for guidance and control functions.	Open/short motor windings, torquer electronics, or power supply; drift.	a. Single failures: No effect due to redundancy. b. Multiple failures: Incorrect outputs to CMGs and/or Thrusters.	a. None b. Loss of attitude control.
Horizon Sensor Assembly	Provides attitude information required for acquisition of Earth-centered orientations; can be used as the attitude control sensor for maintaining coarse adherence to Earth-centered orientations.	Open/short Thermopile, torquer, electronics, or power supply; seal leak; optics failure.	Loss of automatic local-vertical orientation acquisition; loss of coarse local vertical attitude control.	No significant effect; local vertical acquisition must be accomplished manually.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: GN&C

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Star Sensor Assembly	Provides a highly accurate, drift-free attitude reference for the Station in the Earth-centered orientation; used to correct for attitude gyro drift and for navigation computations.	Open/short photo detector, electronics, or power supply; optics failure.	Loss of stellar-inertial attitude data during local vertical orientations.	No significant effect; strapdown platform (attitude gyros) can be updated with the star trackers.
Star Tracker Assembly	Provides a highly accurate, drift-free inertial attitude reference for correcting attitude gyro drift.	Open/short sensor, electronics, torquer, or power supply; optics failure; mechanical gimbal failure.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of stellar-inertial attitude data during inertial orientations.	a. None b. No significant effect; strapdown platform (attitude gyros) can be updated with the Star Sensor Assembly. Loss of all stellar-inertial data (Star Sensor and Trackers) would result in degraded knowledge of Space Station attitude.
Horizon Detector	Provides coarse attitude information used to control communications antennae in the artifical-g mode.	Open/short bolometer, or electronics; optics failure.	Loss of automatic antennae orientation in the artifical-g mode.	No significant effect; antennae management can be accomplished manually until automatic capability is restored.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: GN&C

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Landmark Tracker	Provides data required for implementation of accurate, on-board, autonomous navigation capability.	Open/short detector, electronics, or power supply; optics failure.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of navigation (orbit parameter) data.	a. None b. No significant effect; orbital parameter determination can be accomplished via ground track until on-board capability is restored.
Low-g Accelerometer	Provides data for compensation of navigation errors due to drag variations associated with Station orientations, docked module configuration, and accelerations associated with such events as tank venting and docking.	Open/short electronics or power supply; seal leakage.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of precision orbital parameter data.	a. None b. No significant effect; orbital parameter determination can be accomplished via ground track until on-board capability is restored.
Laser Rendezvous Tracker	Provides range and angle to target data for accomplishing rendezvous with approaching vehicles.	Open/short electronics or power supply; optics failure; gimbal failure.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of ability to track and automatically rendezvous with other vehicles.	a. None b. Loss of ability to automatically recapture unmanned free-flying modules; rendezvous with resupply vehicle dependent upon resupply vehicle capabilities or manual intervention.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: GN&C

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Laser Docking Tracker	Provides range and angle to target data required to accomplish automatic docking.	Open/short electronics or power supply; optics failure.	Loss of automatic docking capability for the affected port.	No significant effect; likelihood of all ports failing is extremely remote.
Alignment Monitoring System	Measures relative alignment between the attitude reference bench mark, remotely located sensors and experiments.	Open/short electronics; optics failure.	a. Single failure: No effect due to redundancy. b. Multiple failures: Loss of precise attitude alignment information between remote sensors/experiments and stellar reference.	a. None b. Degraded navigation accuracy and experiment data.
Sensor Interface Electronics (GN&C Preprocessors)	Provides scaling and buffering between sensors/control devices and digital data bus.	Open/short.	a. Single failures: No effect due to redundancy. b. Multiple failures: One or more of the effects listed for all other GN&C components.	a. None b. Ranges from minor navigation accuracy degradation to loss of attitude control.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: GN&C

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Control Moment Gyro	Primary means of accomplishing attitude stabilization and control.	Open/shorted electronics, torquer motor, pickoffs, spin motor; seal leakage; bearing wear.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of CMG attitude control capability.	a. None b. Attitude control must be achieved with the reaction jet thrusters.
CMG Electronics	Contains electronics required to support operation of the CMGs.	Open/short.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of CMG attitude control capability.	a. None b. Attitude control must be achieved with the reaction jet thrusters.
Reaction Jet Driver Electronics	Contains electronics required for activation of resistor jet and bipropellant thrusters.	Open/short.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of or inadvertent thruster operation.	a. None b. Loss of orbit keeping and automatic CMG desaturation; possible safety hazard during critical periods (e.g. docking).

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: Data Management

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Data Management Subsystem	The Data Management Subsystem provides the required computational and storage capability for the Space Station as well as regulating flow of information between the other subsystems and users.			
OPS Processor/ Experiment Processor	Provides computational/ logical manipulation capability for all data processing.	Open/short electronics resulting in erroneous output.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of data processing capability.	a. None b. Loss of multiple functions, including attitude control.
Main Memory	Storage of data requiring rapid access time.	Open/short electronics resulting in erroneous output; Head failure Tape drive failure Tape failure.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of data processing capability.	a. None b. Loss of multiple functions, including attitude control.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: Data Management

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Bulk Storage Unit	Provides large volume data storage with relatively slow access time.	Open/short electronics; head failure; tape drive failure. Tape failure.	a. Single failures: No effect due to large capacity available.	a. None
			b. Multiple failures: Reduction in amount of experiment data that can be retained. Inability to store.	b. Degraded experiment capabilities. Possible loss of data.
Memory Switch Matrix	Controls access of processors to memory.	Open/short electronics resulting in erroneous output.	a. Single failures: No effect due to redundancy.	a. None
			b. Multiple failures: Loss of data processing capability.	b. Loss of multiple functions including attitude control.
Data Bus Switch Matrix Bus Controller	Controls interface between processors and data bus.	Open/short electronics resulting in erroneous output.	a. Single failures: No effect due to redundancy.	a. None
			b. Multiple failures: Loss of data processing capability.	b. Loss of multiple functions including attitude control.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: Data Management

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Data Bus		Open line.	a. Single failures: No effect due to redundancy.	a. None
			b. Multiple failures: Loss of data processing capability.	b. Loss of multiple functions including attitude control.
RDAU	Provides subsystem/experiment preprocessing and interface with the processors.	Open/short electronics resulting in erroneous output.	a. Single failures: No significant effect due to redundancy for critical functions.	a. None
			b. Multiple failures: Loss of processing capability for critical subsystems.	b. Can cause loss of attitude control.
LMDU	Similar to RDAU with added capability to cause immediate activation of self-contained and external alarm indications.	Open/short electronics resulting in erroneous output.	a. Single failures: No effect due to redundancy.	a. None
			b. Multiple failures: Loss of automatic monitoring of critical situations.	b. Loss of automatic warning and recovery from critical situations.
Film Viewer	Provides capability to analyze film on-board.	Open/short electronics; optics failure; drive failure.	Loss of ability to analyze film on-board.	No significant effect.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: Data Management

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
Film Scanner	Converts film to electronic image for enhancement and statistical analysis.	Open/short electronics; optics failure; CRT failure.	Loss of ability to analyze and enhance film on-board.	No significant effect.
Filter	Employed to enhance film images.	Open/short electronics; optics failure; CRT failure.	Degraded ability to enhance film on-board.	No significant effect.
Display/Console	Used for control and display of films processed on-board.	Open/short electronics; display failure.	Degraded ability to view film images.	No significant effect.
Control Display Console	Used for monitoring and manual intervention relative to DMS.	Open/short electronics; display failure; control failure.	Disables manual participation/intervention capabilities.	None, given that automatic system is functional.
Time Reference Unit	Provides precise time reference for experiment data.	Open/short electronics.	Loss of ability to provide temporal correlation for experiment data.	No significant effect; degraded experiment data.
Command Decoder/ Remote Command Distributors	Used with Control Display Console for monitoring and manual intervention.	Open/short electronics.	Disables manual intervention participation capabilities.	None, given that automatic system is functional.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: RFCS

Item	Function	Failure Effect On		
		Failure Type	Subsystem	Space Station
K_u-Band Power Amplifier	Provides power amplification required for transmission of K_u-band signals.	TWT failure; power supply failure; heater failure.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of K_u-band transmission capability.	a. None b. Loss of TV, Voice and digital communication with ground via DRSS; loss of ranging and command data to FFM.
K_u-Band PM Exciter	Phase-modulates K_u-band carrier with inputs from data and ranging modems.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of K_u-band PM data transmission.	a. None b. Loss of digital/ranging interface with FFMs; degraded digital transmission to ground via DRSS.
K_u-Band FM Exciter	Frequency modulates K_u-band carrier with television, digital, voice, or analog data.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of K_u-band FM data.	a. None b. Loss ofTV, voice, digital, and analog communication with ground via DRSS.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: RFCS

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
S-Band PM Receiver	Provides for reception and demodulation of a phase modulated subcarrier from the DRSS.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of PM data from DRSS.	a. None b. Loss of digital data from ground via DRSS and high gain antenna pointing capability.
S-Band FM Receiver	Provides for reception of frequency modulated data from ground via DRSS.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of FM data from DRSS.	a. None b. Loss of analog data from ground.
S-Band PM Data Receivers	Provides for the reception of a phase modulated data subcarrier and a ranging signal from the FFMs.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of PM data from FFMs.	a. None b. Loss of digital data and ranging information from FFMs.
S-Band FM Video Receivers	Provides for the reception of frequency-modulated video signals from the FFMs.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Multiple failures: Loss of FM data from FFMs.	a. None b. Loss of video information from FFMs.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: RFCS

Item	Function	Failure Effect On		
		Failure Type	Subsystem	Space Station
VHF FM Data Transceiver/ Voice/Ranging	Provides for simultaneous voice and ranging capability with the shuttle vehicle.	Open/short electronics.	a. Single failures: No effect due to redundancy.	a. None
			b. Loss of FM link with shuttle vehicle.	b. Loss of automatic rendezvous capability with shuttle.
VHF FM Voice Transceiver	Provides voice and biomedical interface capability with EVA personnel.	Open/short electronics.	a. Single failures: No effect due to redundancy.	a. None
			b. Loss of FM data between EVA teams and station.	b. Premature termination of EVA.
S-Band Power Amplifier	Provides power amplification required for transmission of S-band signals.	TWT failure; power supply failure; heater failure.	a. Single failures: No effect due to redundancy.	a. None
			b. Loss of ability to transmit S-band FM data.	b. Loss of direct communication link with ground stations.
S-Band FM Exciter	Frequency modulates S-band carrier with TV or wide band digital data.	Open/short electronics.	a. Single failures: No effect due to redundancy.	a. None
			b. Loss of ability to transmit S-band FM data.	b. Loss of direct TV/ wide band digital link with ground stations.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: RFCS

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
S-Band PM Transponder	Provides for PM transmission and reception with ground stations.	Open/short electronics.	a. Single failures: No effect due to redundancy. b. Loss of direct S-band PM link with ground station.	a. None b. Loss of direct voice, data, and ranging link with ground station.
Modems/Terminals	Provide interface buffering between exciters, transceivers, receivers, and the data bus.	Open/short electronics.	Same as exciter, transceiver, or receiver serviced.	Same as exciter, transceiver, or receiver serviced.
High Gain Antenna System Assembly	Transmits K_u-band signals to DRSS and FFMs; receives K_u-band energy and provides conversion to S-band frequencies.	Open/short electronics; drive system failure; mechanical failure.	a. Single failures: Reduced coverage. b. Multiple failures: Loss of K_u-band information exchange.	a. No significant effect. b. Loss of communications with DRSS and FFMs.
VHF Low Gain Antenna System	Receives and transmits information to the shuttle and EVA crews; can also communicate with DRSS at low data rate.	Open/short electrical components; mechanical failure.	a. Single failures: Reduction of coverage. b. Multiple failures: Loss of VHF communications.	a. No significant effect. b. Loss of communication with EVA, shuttle and DRSS during artificial-g mode. Could be critical if failure occurs during docking.

SPACE STATION

FAILURE EFFECT ANALYSIS

SUBSYSTEM: RFCS

Item	Function	Failure Effect On		Space Station
		Failure Type	Subsystem	
S-Band Low Gain Antenna System	Receives and transmits information directly to ground stations.	Open/short electrical components; mechanical failure.	a. Single failures: Reduction of coverage. b. Multiple failures: Loss of S-band communications.	a. No significant effect. b. Loss of direct communication link with ground stations.
K_u-Band Low Gain Antenna System	Provides communication with FFMs during docking and undocking.	Open/short electronics; mechanical failure.	a. Single failures: Reduction of coverage. b. Multiple failures: Loss of wide coverage on K_u-band.	a. Generally, no effect; could be critical during docking. b. Could be critical during docking.