LUNAR RECONNAISSANCE ORBITER PROJECT
CONFIGURATION CHANGE REQUEST

CCR: 431-CCR-000131	**DATE INITIATED**: 2/6/2006	**CCR REV.:**	**CCR REV DATE**: ___________
CCB SECRETARY: DEB YODER	**PROPRIETARY?** ☐ Yes ☒ No	**ITAR SENSTIVE?** ☐ Yes ☒ No	**CCR DUE DATE**: 3/21/2006

CCR TITLE (Brief Description): RELEASE BASELINE VERSION OF LUNAR RECONNAISSANCE ORBITER SAFING OPERATIONS CONCEPT DOCUMENT

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EXTERNAL ORGANIZATION CCR#:	**EXTERNAL ORGANIZATION:**

DOCUMENT (INCLUDE THE DOC. # AND TITLE), CONTRACT, SOFTWARE AFFECTED:

431-OPS-000475 LUNAR RECONNAISSANCE ORBITER SAFING OPERATIONS CONCEPT DOCUMENT

EFFECTIVITY: ☐ ALL ☒ ACS ☐ ACS ANALYSIS ☒ C&DH ☒ COMMUNICATIONS ☐ ELECT. HARNESS ☒ FLT DYNAMICS ☒ GN&C

☐ I&T ☐ LAUNCH VEHICLE ☐ MECHANICAL ☐ MECH. ANALYSIS ☐ EGSE ☐ MGSE ☒ SPACECRAFT ☒ THERMAL ☐ MASS

☒ PAYLOAD/INSTR. ☒ POWER ☒ PROPULSION ☒ SOFTWARE ☒ FLIGHT OPS ☐ WGHT ☒ GND SYS ☐ OTHER _______________

Change Class	**Criticality**	COST? ☒ **NO** ☐ **YES** **If yes, select one basis for estimate:**				
☒ Class I	☐ Emergency	☐ **In-House**	☐ **Actuals**	☐ **ROM**	☐ **Historical Averages**	☐ **Other****
☐ Class II	☐ Urgent	**** If "Other" is chosen for the Basis of Estimate, please explain in Proposed Solution box below:**				
	☒ Routine					

PROBLEM:

The draft baseline version of the Lunar Reconnaissance Orbiter Safing Operations Concept Document (431-OPS-000475) requires baselining by the Level 3 (LRO) CCB.

PROPOSED SOLUTION:

Release the baseline version of the Lunar Reconnaissance Orbiter Safing Operations Concept Document (431-OPS-000475) by the Level 3 (LRO) CCB. Future changes will be initiated by submittal of CCRs. The LRO CMO/Code 431 shall maintain this document.

TYPE OF CHANGE: ☐ Schedule ☐ Interface ☒ Document ☐ Waiver ☐ Deviation ☐ Contract ☐ Other _______________

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BOARD ACTION: □ APPROVED □ APPROVED WITH CHANGE □ DISAPPROVED □ WITHDRAWN □ DEFERRED

Comments

CCB APPROVAL LEVEL REQUIRED [Check appropriate box(es)]:

□	LEVEL 1 NASA HQ	**Signature:**	**Date:**
□	LEVEL 2 RLEP -Ames	**Signature:**	**Date:**
☒	LEVEL 3 LRO - GSFC	**Signature:**	**Date:**

431-OPS-000475
Revision -
Effective Date: To be added upon Release
Expiration Date: To be added upon Release

DRAFT

Lunar Reconnaissance Orbiter Project

Safing Operations Concept

February 6, 2006

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

CM FOREWORD

This document is a Lunar Reconnaissance Orbiter (LRO) Project Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the LRO CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

Questions or comments concerning this document should be addressed to:

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LUNAR RECONNAISSANCE ORBITER PROJECT

DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Rev -			

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
TBR 1	3.1.2	Indications of SBC problems	Q. Nguyen/ GSFC	10/1/2006
TBR 2	Table 4-1	Rate error limit	J. Simpson/ GSFC	10/1/2006
TBR 3	Table 4-1	Solar position error limit	S. Andrews/ GSFC	10/1/2006
TBR 4	Table 4-1	Max. overburn limit	E. Holmes/ GSFC	10/1/2006
TBR 5	Table 4-1	Battery temperature limit	T. Spitzer/ GSFC	10/1/2006
TBR 6	Table 4-1	Out of ground contact timer limit	S. Andrews/ GSFC	10/1/2006
TBD 1	Table 4-1	Attitude and Rate Error time limit	J. Simpson/ GSFC	10/1/2006
TBD 2	Table 4-1	Sun position error time limit	S. Andrews/ GSFC	10/1/2006
TBD 3	Table 4-1	Maximum momentum limit, time limit	E. Holmes/ GSFC	10/1/2006
TBD 4	Table 4-1	Minimum bus voltage limit, time limit	T. Spitzer/ GSFC	10/1/2006
TBD 5	Table 4-1	Maximum battery voltage limit, time limit	T. Spitzer/ GSFC	10/1/2006
TBD 6	Table 4-1	Maximum battery temperature limit, time limit	T. Spitzer/ GSFC	10/1/2006
TBD 7	Table 4-1	Time limit on no PSE response	T. Spitzer/ GSFC	10/1/2006

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1.0 INTRODUCTION

This document describes the system concept for on orbit safing of the Lunar Reconnaissance Orbiter (LRO) during all phases of the mission after launch. This concept will be used to drive the design of specific safing functions on board the spacecraft. This document will be updated as the design matures.

1.1 SCOPE

This document describes safing needs, design features, and top-level monitoring, followed by a summary of system level checks and responses. This document describes the ground and onboard monitoring and the responses needed to maintain spacecraft health and safety.

1.2 DOCUMENTS

1.2.1 Applicable Documents

431-RQMT-000004	Lunar Reconnaissance Orbiter Project Mission Requirements Document
431-OPS-000042	Lunar Reconnaissance Orbiter Project Mission Concept of Operations
431-SPEC-000013	Lunar Reconnaissance Orbiter Electrical Power Subsystem Specification
431-SPEC-000091	Lunar Reconnaissance Orbiter Thermal System Specification

1.2.2 Reference Documents

431-REF-000533	Triana Safing Specification (TRIANA-SPEC-049)
431-REF-000534	MAP Health and Safety Monitoring Requirements (MAP-MSN-SPEC-334)

2.0 SAFING PHILOSOPHY

LRO is a National Aeronautics and Space Administration (NASA) Class C mission, and therefore has selected redundancy. The spacecraft response to failure is minimal, unless that failure means the spacecraft will violate one of the safing goals described in the next section. LRO will nominally fail safe instead of fail operational when it takes action. There are exceptions where hardware or software capabilities exist as backup for critical mission need. The failure response is also based on the time criticality of the failure. The response to events that put the mission at risk quickly is to fail safe quickly. The response to events that do not put the mission at risk quickly is to fail operational, gracefully stepping down the orbiter configuration or just notifying the ground. The goal of this safing approach is to buy time by keeping the orbiter safe until the ground can intervene to continue the mission.

The LRO safing system will monitor events or conditions that could jeopardize mission success, and respond to prevent that loss. The Lunar Reconnaissance Orbiter Mission Requirements Document (431-RQMT-000004) drives the orbiter safing needs. None of the mission design features or actions taken to meet the Mission Requirements Document (MRD) requirements will prevent the successful safing of the obiter.

2.1 POWER

Power system safing will protect the ability to provide adequate power to the orbiter components. There must be enough battery state of charge (SOC) to provide time to react to anomalous conditions and to prevent orbiter components from being damaged or rendered inoperative from undervoltage. To prevent damage to the battery caused by (repeated) deep discharge, battery conditions such as state of charge, voltage, and temperature will be monitored. The power system configuration will be monitored and corrected if need be, as will the orbiter control system.

During sun acquisitions and eclipses, the driving requirement is to limit a transient discharge of the battery to no less than 20% state of charge in any survivable condition (refer to Lunar Reconnaissance Orbiter Electrical Power Subsystem Specification [431-SPEC-000013], EPS-3.3.5.1.5). This requirement puts a limit on how long sun acquisition can take, and how well it has to point the orbiter to the sun. Also, in case of failure, loads will be shed to reduce the current drain on the battery.

In addition, all power negative operations are limited such that the battery state of charge does not go below 70% (MRD-99). This limitation puts attitude and duration constraints on critical events like the Lunar Orbit Insertion burn. Proper power system configuration is necessary for performing the LOI burn.

Proper power system functioning enables proper functioning of the thermal control system’s survival and operational heaters, which keep all hardware and instrument components within their survival temperature ranges (MRD-34, -79, -100).

2.2 COMMAND & DATA HANDLING

The Command and Data Handling (C&DH) system safing will protect the ability of the ground and the spacecraft to communicate with and control the orbiter. C&DH safing will also prevent the orbiter from being in an uncontrolled state for long enough to endanger the orbiter health and safety. For the orbiter to be under control, the absolute minimum configuration needed is:

unswitched services (C&DH, S-Comm card, Ka-Comm card, Receiver, survival heaters)

jumpered switched services (reaction wheels, solar array [SA] gimbals)

Sun Safe Attitude Control System (ACS) control mode

In the event of any recoverable system failure, LRO shall not go uncontrolled for more than 2 minutes (MRD-158). To ensure the proper orbiter configuration for control, the safing process will include commands to create the minimal control configuration. There are several hardware and software configuration errors that could cause a loss of control, and these will be monitored and corrected onboard. Hardware-only commands are needed to bypass software errors, and software commands are needed to bypass hardware errors. Flight software (FSW) manages the watchdog timers, but if the timer runs out, the hardware issues a reset command.

This C&DH safing function includes comm system component safing and attitude control for antenna orientation. The driving comm. requirement is to maintain the ability to command and monitor the spacecraft when in view of the ground (MRD-119, -120, Sec. 3.3.6.8, 3.3.6.9). S-band comm is used to support operational mission telemetry, tracking and command. Also, it allows the ground to quickly respond to anomalies and take action if necessary. There are safing checks that monitor the S-comm card and there is an onboard ground contact timer. If comm is lost for a moderate amount of time, the spacecraft will reset the S-Comm card. If comm is lost for an extended period of time, the spacecraft will then enter a safe attitude while it waits for ground contact.

Critical events like the Lunar Orbit Insertion (LOI) burn will be planned to maintain ground contact during the maneuver. Also, because C&DH issues can lead to loss of control, a main processor reset is one of the conditions identified that would cause the LOI burn to be aborted.

2.3 INSTRUMENTS

The instrument safing system is the spacecraft’s monitoring and response to conditions that threaten the health and safety of the various instruments. The primary health and safety concerns for the instruments are bus voltage, component temperature, and sun exposure. These conditions are managed by the power system safing, monitoring the spacecraft thermal configuration, and by monitoring and controlling the orbiter attitude.

The instruments are designed to operate in a particular voltage range: Subsystems/instruments shall operate nominally at 21-35 volts direct current (VDC) (MRD-32). The power system safing design is described above.

The instruments are also designed to operate within a certain temperature range. Both the solar input (via orbiter attitude) and the heater configurations (via thermal system design and settings) will be monitored and controlled to meet the driving thermal requirements: Subsystems/ instruments shall comply with the Lunar Reconnaissance Orbiter Thermal System Specification (431-SPEC-000091) (MRD-34).

Finally, many of the instruments can be damaged by sun exposure. LRO shall never intentionally allow the Sun to enter, move through, or remain in the instrument solar fields of regard (MRD-52).

Specifically, the Lunar Reconnaissance Orbiter Camera (LROC) Narrow Angle Camera (NAC) field of regard is 3 degrees (deg), and it can survive a maximum 3 second (sec) sun exposure, so the minimum safe rate is greater than or equal to 1 deg/sec. The NAC cannot be safed. The Lunar Orbiter Laser Altimeter (LOLA) can survive sun exposure at rates greater than 1 deg/sec; is also cannot be safed. The Lyman-Alpha Mapping Project (LAMP) cannot allow any sun exposure when it’s operating, but it can be safed. The Diviner Lunar Radiometer Experiment (DLRE) cannot allow any sun exposure, but it can be safed. Cosmic Ray Telescope for Effects of Radiation (CRaTER) and Lunar Exploration Neutron Detector (LEND) are not directly affected by exposure to sunlight

Nominal operations will always keep the sun on the correct side of the orbiter, away from the instrument boresights. When the orbiter is acquiring the sun, there will be a stay out zone that prevents the sun from getting in the instruments fields of view.

The sun avoidance criteria must be met even if the spacecraft is out of control for the whole two minutes allowed in MRD-158. If the orbiter moves at 1 deg/sec or more when out of control, there are no more than 90 seconds of time available before an instrument will see the sun (assuming a nominal 90 degree rotation is needed to get the sun in the instrument boresights). However, at that rate, no damage would be done if the orbiter weren’t under control at that time.

If the spacecraft is moving at less than 1 deg/sec, there is more time to get under control before the sun could potentially damage an instrument. However, if the orbiter is not under control soon enough, the sun exposure at the lower rate would damage at least one instrument.

To move 90 degrees in two minutes, the spacecraft would have to move at an average rate of 0.75 deg/sec. Several instruments would not be safe if the two minute out of control period is exceeded at the lower rates.

The instrument safing constraints are shown graphically in Figure 2-1.

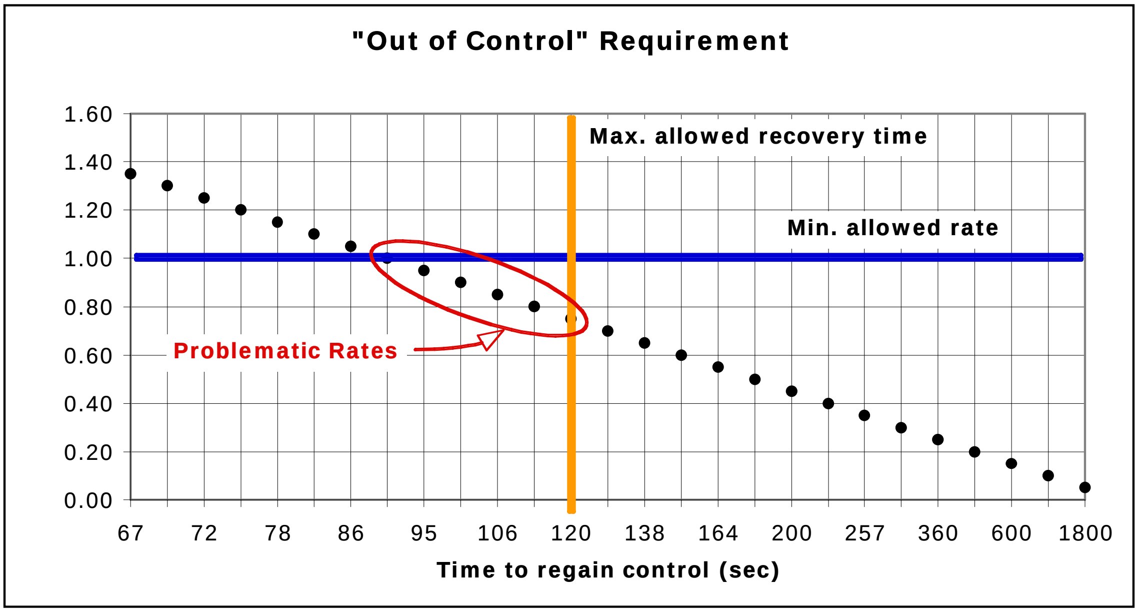

Figure 2-1. Instrument Safing Constraints

The extremely narrow fields of view of the most sensitive instruments mitigate this risk. To get the sun in one of the fields of view at exactly the wrong rate is difficult. For example, the LAMP Limb Termination Sensor (LTS) field of view is ~ 1° x 10° (= 0.003 steradian), which is 0.003/4π = 0.024% of the entire sky.

2.4 CONTROL

The goal of the Control safing is to control and monitor the correct orbiter orientation, system momentum, and control system configuration for all mission phases. In addition, critical events like sun acquisitions and the LOI burn must be performed for the mission to be successful. Much of the safing functionality required to meet these requirements will be implemented in flight software. The ACS control mode diagram, which illustrates nominal ACS control mode functionality and transitions, plus transitions for safing, is shown in Figure 2-1.

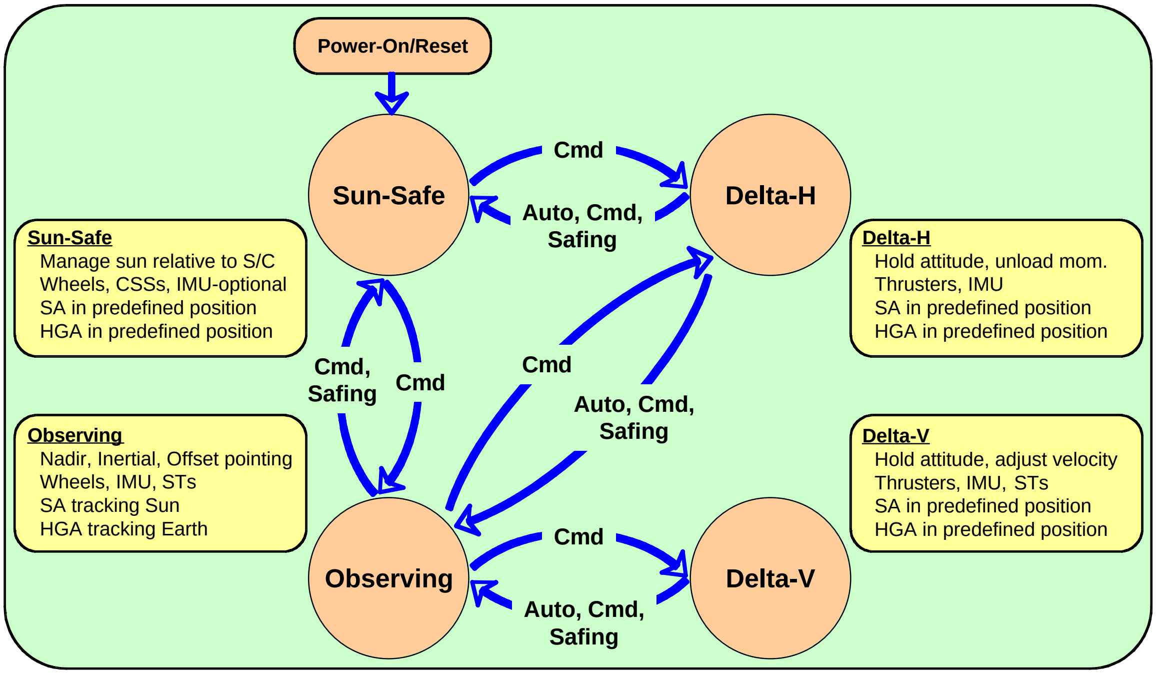
Power-On/Reset
Sun-Safe
Delta-H
Observing
Delta-V
Cmd
Auto, Cmd, Safing
Cmd, Safing
Cmd
Cmd
Auto, Cmd, Safing
Cmd
Auto, Cmd, Safing
Sun-Safe
Manage sun relative to S/C
Wheels, CSSs, IMU-optional
SA in predefined position
HGA in predefined position
Observing
Nadir, Inertial, Offset pointing
Wheels, IMU, STs
SA tracking Sun
HGA tracking Earth
Delta-H
Hold attitude, unload mom.
Thrusters, IMU
SA in predefined position
HGA in predefined position
Delta-V
Hold attitude, adjust velocity
Thrusters, IMU, STs
SA in predefined position
HGA in predefined position

Figure 2-2. ACS Control Mode Diagram

The ACS shall maintain LRO's orientation, as well as that of its SA and high gain antenna (HGA), throughout the mission (MRD-84) to maintain the integrity of all systems and to meet mission objectives.

The Control safing includes sun pointing at launch vehicle separation (MRD-88) and whenever commanded to do so based on orbiter safing constraints (MRD-8, MRD-20). The spacecraft will operate in as simple a mode as possible to achieve a power-positive orientation (MRD-89, -90, -91). Since this is the lowest level control mode with no backup, this control mode must acquire the sun; once the battery is depleted, there is no way to recover the spacecraft. As described in the C&DH section, this will be implemented using the minimum configuration of hardware. There is sun avoidance programmed into the sun acquisition controller to avoid damaging the instruments.

The LOI underburn safing is to continue the burn as long as necessary to allow the moon to capture LRO into lunar orbit. The LOI overburn safing is to exit the burn as soon as possible to prevent LRO colliding with the moon. The recoverable conditions identified that stop the burn are a processor reboot and an incorrect attitude. This is the most time-critical function of the mission. If safing and recovery is not fast enough or robust enough, the burn will not complete, and the moon will not capture LRO (MRD-10, -11). The nominal burn targets the lowest safe lunar orbit and maximizes the range of underburn that will still achieve lunar orbit.

At all times during the mission, attitudes and rates will be monitored to ensure that mission objectives are being met. The main response to failure will be to transition to the next lowest mode, for example, Delta V to Observing, or Observing to Sun Safe. If system momentum limits are exceeded, the actuators will not be able to control the orbiter due to torque saturation.

2.5 THERMAL

The goal of the Thermal system safing is to protect the ability of the orbiter components to function properly. That means protecting the components against degradation or failure, which can reduce mission performance or component lifetime. The thermal control system shall maintain all component and structural interface temperatures within their appropriate limits during normal operations as specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091) (MRD-78). In addition, the LRO thermal control system shall maintain all component and structural interface temperatures to be within their survival limits during all phases of the mission as specified in the Lunar Reconnaissance Orbiter Thermal Systems Specification (431-SPEC-000091) (MRD-79). The thermal limits include thermal gradients, so even off-nominal operations shall be limited such that component temps can be maintained within set limits (MRD-100).

Thermal safing is primarily about maintaining the proper spacecraft orientation, and maintaining the proper thermal system configuration. The spacecraft will monitor and control the attitude, and the spacecraft and the ground will monitor the thermal system configuration.

3.0 MONITORING

3.1 FROM THE GROUND

The ground system will monitor all telemetry from the spacecraft. There will be yellow and red limits indicating the degree of violation, and the type of response that is required. Depending on the type of problem, the ground can send either software commands to safe the orbiter, or send hardware decoded commands that act independently of the flight software. Attitude and thermal configurations and performance are continuously monitored when the orbiter is in contact with the ground. This section summarizes the monitoring that is needed for any ground-generated hardware commands. These hardware commands are only available from the ground to the S-Comm card, to prevent the flight software from sending these commands repeatedly.

3.1.1 Comm System Monitoring

The ground will monitor if the S-Comm card uplink and/or downlink is unresponsive. This will be indicated by lack of SpaceWire response, lack of accepted ground commands, or lack of telemetry when the transmitter is commanded ON. An S-comm card reset is needed to clear this problem.

3.1.2 Processor Monitoring

The ground will monitor if there is a Single Board Computer (SBC) problem. There are many indications of this, such as bad orbiter attitude, lack of response to commands (**TBR**). A processor reset command is needed to clear this problem.

In addition, if there are continuing SBC problems, such as multiple resets, if the reset command doesn't solve the original problem, or if the Housekeeping Input/Output (HK I/O) card is unresponsive, a processor power cycle command is needed to completely reset the SBC or HK I/O.

3.1.3 Power System Monitoring

The ground will monitor the power system for conditions such as low bus voltage, low battery state of charge, and battery temperature. If there is a limit violation, the load on the power system can be reduced with a load shed command.

The Solar Array Module (SAM) in the Power Switching Electronics (PSE) may be commanded to various configurations during the course of the mission, or in response to failure. The SAM needs to be reset to a normal operating condition for troubleshooting or for failure recovery.

3.2 ONBOARD

The onboard monitoring capabilities are separated into software written specifically for ACS fault detection and handling (FDH) and generic flight telemetry and SBC monitoring utilities. There are predefined flight software command sequences that will be executed when necessary to correct problems and respond to anomalies. In addition, the ground and the flight software can command the SBC to send hardware commands directly to other cards, bypassing FSW commands. This section summarizes the monitoring that is needed for any FSW or ground-generated SBC hardware commands.

3.2.1 Comm System

The software monitors if the S-Comm card uplink and/or downlink is unresponsive. This will be indicated by either lack of SpaceWire response, lack of Ground Commands for a longer than nominal between ground contact period of time (Barker timer), or lack of accepted ground commands. An S-comm card reset command from the SBC is needed to clear this problem.

3.2.2 Power System

If the software determines that the PSE is nonresponsive, the SBC will send a reset command to the PSE.

The FSW will monitor the power system for conditions such as low bus voltage, low battery state of charge, and battery temperature. If there is a problem, the SBC will send a command to create a default state for the PSE. This command will also be used during failure recovery.

If the FSW determines that a power system condition such as low bus voltage or low battery state of charge exists, the SBC can send a command to maximize the power input the system.

3.2.3 SBC Watchdog

There is an SBC watchdog timer that is used for software protection. If the software goes astray and doesn't do what it's supposed to do, the watchdog goes off. There is a FSW task that manages the watchdog timer. That task takes input from many other tasks (the ones labeled 'critical') and if all are reporting that there is no problem, then the watchdog timer is set to a high value and begins a new countdown. If after a while some task or other does not report in, the managing task lets the timer expire, and then the watchdog timer (a piece of hardware), performs a hold on the SBC reset line. This acts like a power cycle for the SBC, so that after the reset, the SBC processor is in a default power-up configuration.

3.2.4 Software Functions

The data monitoring done “inline” in the ACS FSW will handle things like missed gyro counts, or occasional missed component packets. The software response will be to use previous data for that cycle, if it doesn’t violate orbiter health and safety.

The Limit Checker/Telemetry and Statistics Monitor (LC/TSM) function monitors defined telemetry points, and issues a call to execute a relative time command sequence if certain conditions are met. Actions are carried out by Relative Time Sequence (RTS) commands under the Stored Command (SC) processor task.

4.0 SYSTEM RESPONSE

The system level checks performed in flight software are the highest level of onboard monitoring and are directly related to maintaining spacecraft health and safety. Deciding when and how to respond to this check is based on the goals outlined above, using the available FSW and hardware capabilities. These checks are summarized in Table 4-1, with the top-level health and safety concerns in **bold** in the "Rationale" column.

Table 4-1. System Level Safing Summary

Safing Trigger	Definition	Spacecraft Action	Rationale	Notes
Attitude and Rate Error	Attitude error > 5 deg, rate errors > 0.1 deg/sec (**TBR**) for **TBD** secs.	Transition to lower control mode.	Ensure orbiter pointing for **power**, **thermal**, and **instrument** reasons.	Uses all available attitude sensors.
Sun Position Error	Solar position within 60 deg (**TBR**) of +Z axis for more than **TBD** seconds.	Transition to lower control mode.	Ensure overall orbiter pointing for thermal and **instrument** reasons.	Instrument sun constraints cannot be violated.
High System Momentum	System momentum > **TBD** Nms for more than **TBD** seconds.	1. Exit thruster mode. 2. Transition to Sun Safe Mode. 3. Close isovalve.	Ensure that the spacecraft is operating within the actuator capacity (wheels or thrusters), to prevent **attitude** errors and orbiter **tumbling**.	Requires good data from wheels and a rate source. Limits, actions are mission phase and ACS control mode dependent.
Burn Time Exceeded	Time in thruster mode > 105% (**TBR**) of commanded.	Exit thruster mode.	Prevent loss of **attitude** control, ensure orbiter achieves proper orbit or momentum.	Prevents fuel loss, guards against control mode exit criteria failure.
Low Bus Voltage	Voltage < **TBD** V for **TBD** sec.	1. Load shed. 2. Load shed and transition to Sun Safe Mode.	Safeguard against errors in **power** management or **attitude** control.	From incorrect attitude, incorrect array pointing, or power problem.
High Battery Voltage	Battery voltage > **TBD** V for **TBD** seconds.	Reduce charge control.	Prevent battery damage due to **overvoltage or overcharging.**	Shed loads, reduce rate of charge.
High Battery Temperature	Battery temp > 40 deg C (**TBR**) for **TBD** seconds.	Isolate battery.	Prevent battery damage due to **overheating**.	Shed loads, reduce rate of charge.
SBC Watchdog Timeout	Watchdog timer = 0	Hold on the SBC reset line.	Protect against SBC **not being in control**.	Acts like power cycle.
Command Watchdog Timeout	Lack of ground contact for > 28 (**TBR**) hours.	1. Reset S-band comm card. 2. Transition to Sun Safe Mode.	Protect against **comm**. card problem preventing ground contact.	Orbiter attempt to restore comm.
Unresponsive PSE	Lack of telemetry or no response to SBC commands for **TBD** seconds.	Send reset command to PSE.	Ensure that **power** system configuration can be monitored or changed.	Reset PSE without changing any settings.

Appendix A. Abbreviations and Acronyms

Abbreviation/ Acronym	DEFINITION
ACS	Attitude Control System
C&DH	Command and Data Handling
CCB	Configuration Control Board
CM	Configuration Management
CMO	Configuration Management Office
CPU	Central Processing Unit
CRaTER	Cosmic Ray Telescope for the Effects of Radiation
deg	degrees
FDH	Failure Detection and Handling
FSW	Flight Software
HK I/O	Housekeeping Input/Output
LAMP	Lyman Alpha Mapping Project
LC	Limit Checker
LEND	Lunar Exploration Neutron Detector
LOI	Lunar Orbit Insertion
LOLA	Lunar Orbiter Laser Altimeter
LRO	Lunar Reconnaissance Orbiter
LROC	Lunar Reconnaissance Orbiter Camera
LTS	Limb Terminator Sensor
MAP	Microwave Anisotropy Probe
MRD	Mission Requirements Document
NAC	Narrow Angle Camera
NASA	National Aeronautics and Space Administration
Nms	Newton-meter-seconds
PSE	Power Switching Electronics
RTS	Relative Time Sequence
SAM	Solar Array Module
SBC	Single Board computer
SC	Stored Command
SOC	State of Charge
TBD	To Be Determined
TBR	To Be Refined
TSM	Telemetry and Statistics Monitor
V	Volts
VDC	Voltage, Direct Current