Monitor and Control - Electronics: Technical Requirements Specification

020.30.45.00.00-0002-REQ

Status: **Released**

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Change Record

Version	Date	Author	Affected Section(s)	Reason
04	2018-05-15	W. Koski	All	Initial draft
05	2018-07-26	J. Baca	All	Revised by J. Baca (unformatted)
05	2018-07-26	W. Koski	All	Formatted, Budget Assumptions, Risks added
06	2019-09-02	S. Durand	All	Small edits
07	2018-10-29	W. Koski	All	James Robnett's RID input
08	2018-11-13	W. Koski	All	Jim Jackson's Block Diagram Alignment
09	2019-04-24	S. Durand	All	Small edits, addressed TBDs
10	2019-04-29	W. Koski	Page 6, 12	Corrected RD04 Author Spelling, Added Section 4.9
11	2019-07-23	L. Leyba-Newton	All	Reformatted, added needed requirements, and added clarification/traceability
12	2019-07-24	R. Selina	All	Updated for reference design release
A	2019-07-29	A. Lear	All	Prepared PDF for signatures and release
A.01	2020-03-16	W. Koski	All	Major Rewrite by Owner. Additional input by R. Selina, J. Jackson, L. Leyba-Newton, and R. Hiriart Changed Rev B to Rev A.01
A.02	2020-05-13	W. Koski	Section 4	Updated Traceability to Electronics Specification Document
A.03	2021-04-29	W. Koski	All	RID Corrections
A.04	2022-05-22	W. Koski	All	Requirements from M&C Concept Document
A.05	2022-06-08	W. Koski	All	RID Corrections
B	2022-06-13	T. Kusel	All	Finalize document for System CDR Release.

Table of Contents

1 Introduction 5
1.1 Purpose 5
1.2 Scope 5
2 Related Documents and Drawings 5
2.1 Applicable Documents 5
2.2 Applicable ICDs 6
2.3 Reference Documents 7
3 Overview of the Subsystem 7
3.1.1 M&C HIL 7
3.1.2 M&C LRUs 7
3.2 M&C LRUs product breakdown and context 7
3.3 General M&C HIL Description 8
4 Requirements Management 10
4.1 Requirements Definitions 10
4.2 Requirements Flow-Down 10
4.3 Verb Convention 12
5 Assumptions 12
6 Environmental Conditions 12
7 Key Performance Parameters 12
8 Subsystem Requirements 13
8.1 M&C HIL Functional and Performance Requirements 13
8.2 MIB and M&C HIL Electronics Functional Requirements 13
8.3 Monitor and Control - Electronics LRU Functional Requirements 16
8.4 Environmental Requirements 25
8.5 Maintenance, Availability, and Reliability Requirements 26
8.6 Lifecycle Requirements 27
8.7 Safety Design Requirements 28
8.8 Monitor and Control – Electronics Electromagnetic Compatibility Requirements 30
9 Documentation Generation and Storage Goals 31
9.1 Technical Documentation 31
9.2 Software and Software Documentation 32
10 Deleted Requirements 32
11 Verification 33
12 Appendix 38
12.1 Abbreviations and Acronyms 38

List of Figures

Figure 1: Context and product breakdown of the HIL subsystem.....8
Figure 2: M&C HIL Decomposition 9
Figure 3: Requirements Flow-Down: Monitor and Control – Electronics.....11

1 Introduction

1.1 Purpose

This document presents the complete set of Level 2 subsystem requirements that guide the design and development of the ngVLA Monitor and Control Electronics subsystem. Requirements described in this document are derived from applicable ngVLA System Requirements and System-Level Specification documents as listed in the Applicable Documents table. The engineering process and requirements hierarchy that govern this specification are defined in [AD12] and [AD13] respectively.

The content of these requirements is at the subsystem level, conforming to the system architecture [AD14], but aims to be implementation agnostic within the subsystem boundaries. Some assumptions about the subsystem may be given, but only to the degree necessary to unambiguously define the subsystem requirements.

1.2 Scope

The scope of this document is the specification of the Monitor and Control Electronics Subsystem, formerly named the Hardware Interface Layer (HIL) with configuration item number 30.45.00.00.

This specification includes:

- Assumptions on which the requirements are based.
- Definition of environmental conditions to be used in the definition of requirements.
- A complete set of requirements for the subsystem needed for the development, operation and maintenance of the subsystem, including interface requirements that are derived from the applicable list of ICDs.
- Numbering of all requirement and establishment of traceability to higher level requirements.
- Verification requirements and their traceability to the subsystem main requirements.
- Identification of Key Performance Parameters (KPPs) at the subsystem level.

The Level 2 Subsystem Requirements, along with detailed explanatory notes, are found in Section 8. The notes contain elaborations regarding the meaning, intent, and scope of the requirements. These notes form an important part of the definition of the requirement. In many cases, the notes contain an analysis of how the numeric values of requirements were derived to ensure correct interpretation of the requirements and to resolve ambiguity.

In cases where the requirements analysis is incomplete, such values are marked with TBD or TBC, which need to be resolved before the final specification is published.

2 Related Documents and Drawings

2.1 Applicable Documents

The following documents are applicable to this Requirements Specification to the extent specified. An understanding of these documents is necessary to fully comprehend the scope of this Requirements Specification. In the event of conflict between the documents referenced herein and the content of this

Requirements Specification, the content of the highest-level specification (in the requirements flow-down) shall be considered the superseding requirement.

Ref. No.	Document Title	Rev/Doc. No.
AD01	System Requirements	020.10.15.10.00-0003-REQ
AD02	System-Level Architecture Model	020.10.20.00.00-0002-REP
AD03	System Environmental Specifications	020.10.15.10.00-0001-SPE
AD04	System Electromagnetic Compatibility and Radio Frequency Interference Mitigation Requirements	020.10.15.10.00-0002-REQ
AD05	Level 1 Safety Requirements	020.80.00.00.00-0001-REQ
AD06	Antenna Electronics Environmental Control System: Technical Requirements	020.30.60.00.00-0001-REQ
AD07	Central Signal Processor: Technical Requirements	020.40.00.00.00-0001-REQ
AD08	Computing & Software: Preliminary Requirements	020.50.00.00.01-0001-REQ
AD09	Monitor & Control System: Concept	020.50.25.00.00-0002-DSN
AD10	ngVLA System Electronics Specifications	020.10.15.10.00-0008-REQ
AD11	Security Management Plan and Requirements	020.80.00.00.00-0003-REQ
AD12	ngVLA Systems Engineering Management Plan	020.10.00.00.00-0001-PLA
AD13	ngVLA Requirements Management Plan	020.10.15.00.00-0001-PLA

2.2 Applicable ICDs

The following ICDs define the external boundary of this subsystem and are applicable to its specification:

Ref. No.	Document Title	Rev./Doc. No.
AD14	Monitor & Control Hardware Interface Layer: Common Device Interface Control Document	020.30.00.00.00-0004-ICD
AD15	IRD Monitoring & Control ICD	020.10.40.05.00-0001-ICD
AD16	FED Monitoring & Control ICD	020.10.40.05.00-0015-ICD
AD17	WVR Monitoring & Control ICD	020.10.40.05.00-0025-ICD
AD18	CRY Monitoring & Control ICD	020.10.40.05.00-0046-ICD
AD19	PSU Monitoring & Control ICD	020.10.40.05.00-0054-ICD
AD20	EEC Monitoring & Control ICD	020.10.40.05.00-0066-ICD
AD21	MON Monitoring & Control ICD	020.10.40.05.00-0071-ICD
AD22	DBE Monitoring & Control ICD	020.10.40.05.00-0076-ICD
AD23	RTD Monitoring & Control ICD	020.10.40.05.00-0077-ICD
AD24	ATF Monitoring & Control ICD	020.10.40.05.00-0078-ICD
AD25	BMR to Antenna Electronics ICD	020.10.40.05.00-0040-ICD
AD26	MCL to HIL ICD	020.10.40.05.00-0075-ICD
AD27	AFD to Antenna Electronics ICD	020.10.40.05.00-0041-ICD

2.3 Reference Documents

The following references provide supporting context:

Ref. No.	Document Title	Rev/Doc. No.
RD01	Military Handbook, Reliability Prediction of Electronic Equipment	MIL-HDBK-217F
RD02	Non-electronic Parts Reliability Data	NPRD-95
RD03	Electromagnetic Compatibility	IEC 61000-3-5
RD04	ngVLA Level 1 Requirements for Reliability, Availability and Maintainability	020.10.50.00.00-0003-MEM

3 Overview of the Subsystem

The ngVLA Monitor and Control – Electronics Subsystem includes the Monitor & Control Hardware Interface Layer (M&C HIL) and the Monitor & Control Line Replaceable Units (M&C LRUs).

Because the ngVLA Monitor and Control – Electronics System touches upon or is part of all equipment in the antenna, sub-buildings, and the central electronics, there shall be a high level of collaboration with all other Integrated Product Teams (IPTs) as their requirements will influence the Monitor and Control Requirements and vice versa. The M&C HIL Interface requirements will need further decomposition that will take place in the conceptual design stage.

3.1.1 M&C HIL

This consists of the core ngVLA Project M&C Interface Board (MIB), similar to the EVLA Project Module Interface Board (MIB), and other related expansion boards or sub-boards that provides more interface resources for an LRU. A MIB that has one or more expansion boards is known generically as the MIB Stack.

3.1.2 M&C LRUs

The Line Replaceable Units (LRUs) that will be developed for ngVLA Monitor and Control – Electronics will be driven from requirements for LRUs contained in 020.10.15.10.00-0008-REQ System Electronics Specifications [AD10]. The specific LRUs that are applicable to this specification are defined in the following section.

3.2 M&C LRUs product breakdown and context

The product breakdown of the M&C LRUs and the interfaces to external subsystems is shown in Figure 1 below.

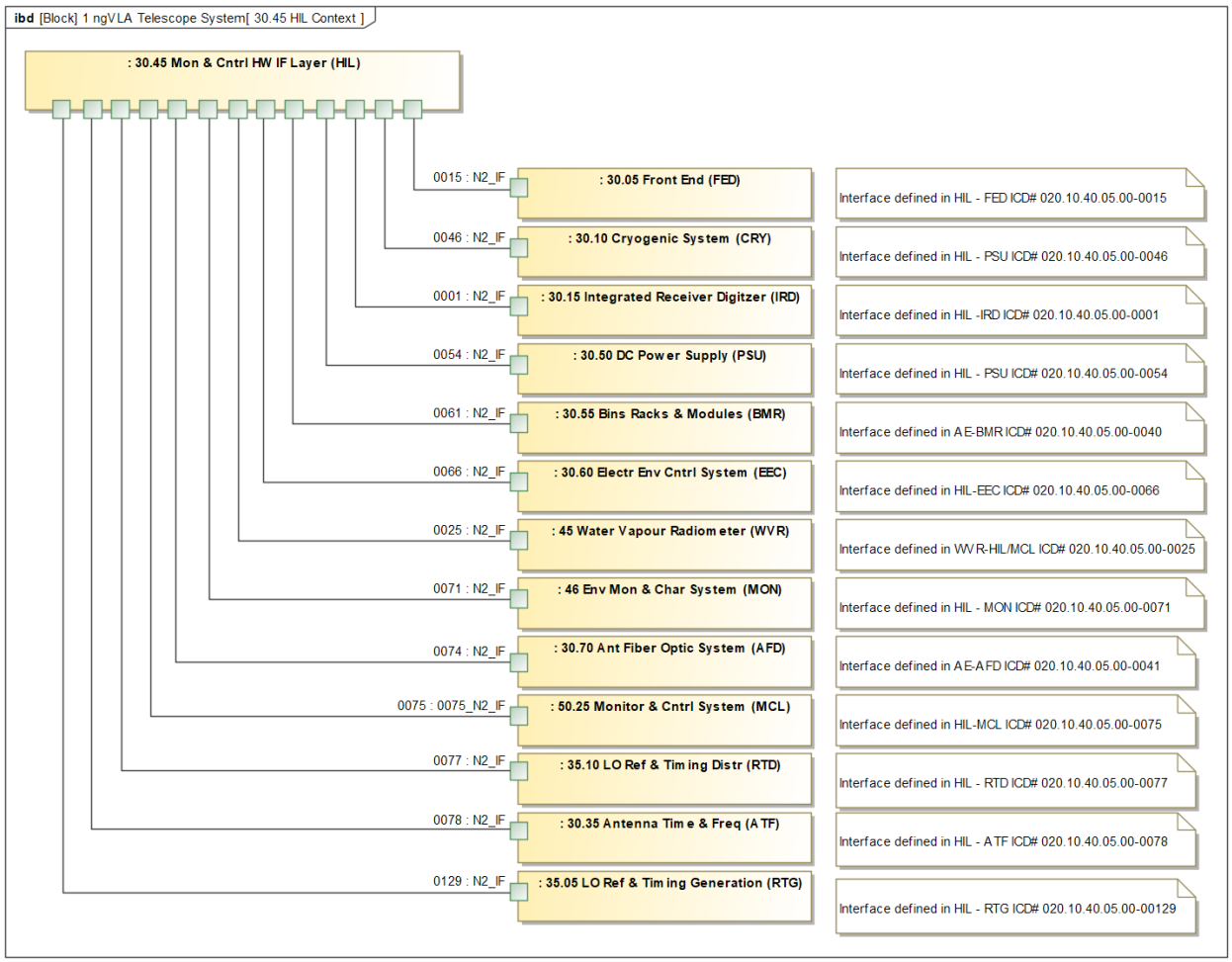

Figure 1: Context and product breakdown of the HIL subsystem

3.3 General M&C HIL Description

The system will consist of the ngVLA M&C Interface Board (MIB), similar to the EVLA Module Interface Board (MIB), which serves as the Hardware Interface Layer (HIL) between Monitor and Control - Software and Devices or LRU that need to be monitored and controlled. Other items such as digital and analog expansion boards are considered to be M&C HIL to provide flexibility, simplicity, and standardization for LRU design. In Figure 2: M&C HIL Decomposition further expands upon the various M&C LRU's and their planned positions on a ngVLA Antenna. The M5xx LRU's that have parenthesis around them such as (M502), are LRUs that will have a MIB. An LRU that isn't in parenthesis such as the M500 will not contain a MIB, but can contain logic to support M&C HIL requirements.

The MIB based LRUs will support LRU's and/or other electronics that do not have or can't have an integrated MIB in them. An example is the (FED) from Figure 1. Those LRU's in that Block which are highly RFI sensitive are supported by the M507 for Monitor & Control via a controlled communication channel.

The M&C system is an Ethernet fiber-based system that provides a great deal of RFI immunity versus copper connections. Other systems will be utilizing fiber as well throughout the antenna, so the Antenna Fiber Distribution (AFD) will also manage the M&C fiber infrastructure.

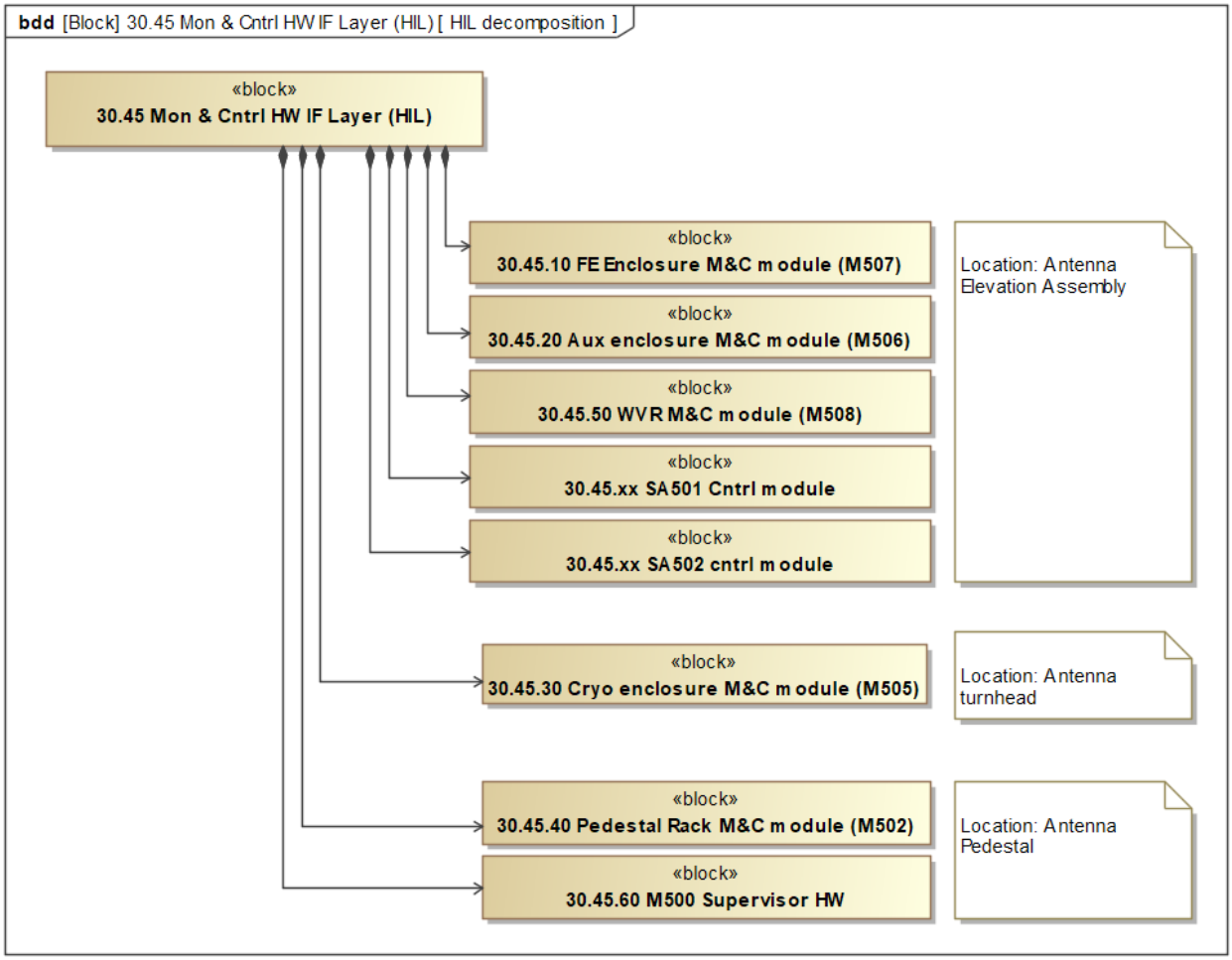

Figure 2: M&C HIL Decomposition

4 Requirements Management

4.1 Requirements Definitions

The following definitions of requirement "levels" are used in the ngVLA program. The requirements in this document are at the L2 subsystem level.

Requirement Level	Definition
L0	User requirements expressed in terms applicable to their needs or use cases (Science Requirements or Stakeholder Requirements)
L1	Requirements of the System, expressed in technical functional or performance terms (System Level Requirements)
L2	Requirements that define a specification for an element of the system, presuming a system architecture (Subsystem Requirements)

4.2 Requirements Flow-Down

The Requirements Flow-Down is diagrammed in *Figure 3: Requirements Flow-Down: Monitor and Control – Electronics*.

At Level 0: Science and Stakeholder Requirements contains Level 0 Safety Requirements and Land Acquisition & Regulatory Compliance. They all flow into System Requirements [AD01] at Level 1.

At Level 1: System Requirements [AD01] contains Security Specifications [AD11], Level 1 Safety Specifications [AD05], Environmental Specifications [AD03], and Compatibility and Radio Frequency Interference Mitigation Requirements [AD04] They all flow into Computing & Software Requirements [AD10] at Level 2, but also Electronics Specifications [AD10] at Level 1.1 and Monitor and Control Electronics Interface Layer: Technical Requirements Specification (This Document) at Level 2.1.

At Level 1.1: Electronics Specification [AD10] flows into Monitor and Control Electronics Interface Layer: Technical Requirements Specification (This Document) at Level 2.1

At Level 2: Computing & Software Requirements [AD08] flows into Monitor and Control Electronics Interface Layer: Technical Requirements Specification (This Document) at Level 2.1. Additionally, a parallel informs path via the Monitor and Control Concept document [AD09] was generated to clarify certain requirements.

This document (Monitor and Control Electronics Interface Layer: Technical Requirements Specification) must respond and be traceable to pertinent requirements generated by three paths: Electronics Specifications, Computing & Software Requirements, and System Requirements.

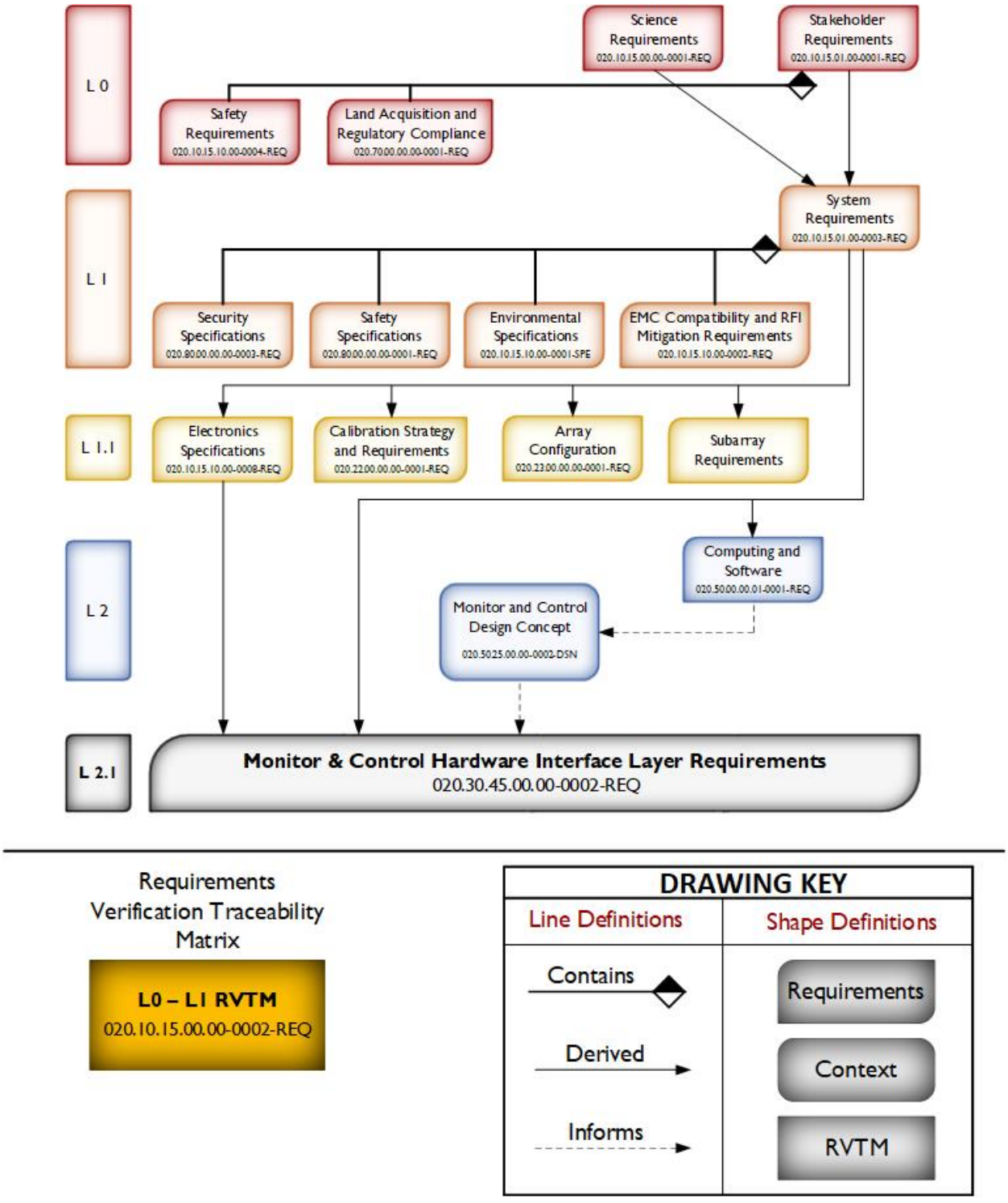

Figure 3: Requirements Flow-Down: Monitor and Control – Electronics

4.3 Verb Convention

This document uses "shall" to denote a requirement. The verbs "should" and "must" denote desired but not strictly required parameters. "Will" denotes a future happening. Desired but not required features are noted as "desirable" or "goals."

5 Assumptions

The following assumptions are made in the definition of these subsystem requirements:

- Subsystem requirements apply to performance before any operational calibration corrections are applied unless explicitly stated otherwise.
- Hardware requirements apply to a properly functioning system under the precision operating environmental conditions unless explicitly stated otherwise.
- Hardware requirements assume that all system parts that would normally be in place during observations are working within their respective specifications (e.g., HVAC, RTP system) unless explicitly stated otherwise.
- All LRU Requirements are only for Monitor & Control Electronics LRUs.

6 Environmental Conditions

Environmental conditions are from System Environmental Specification [AD03] and those requirements are in Section 7.4 of this document. It is important to note that Monitor and Control Electronics will have to have extended operating parameters such as Operating Temperature in order to detect, protect, and report those problems in LRUs when installed in same.

7 Key Performance Parameters

No Key Performance Parameters have been identified for M&C HIL.

8 Subsystem Requirements

8.1 M&C HIL Functional and Performance Requirements

These requirements apply to a properly functioning system under operating environmental conditions unless otherwise stated.

8.2 MIB and M&C HIL Electronics Functional Requirements

Parameter	**Req. #**	**Value**	**Traceability**
MIB Ethernet Interface	MCH0101	The MIB shall provide a high-level Ethernet Interface to the Computing and Software system.	CSS6033
MIB Protocol	MCH0102	The MIB shall utilize Ethernet Protocols.	CSS6033
MIB Ethernet Transceiver Interface	MCH0103	The MIB Ethernet Interface shall be over Fiber to the Computing and Software system.	EMC0310 through EMC0312
MIB Ethernet Transceiver Replaceability	MCH0104	The Ethernet Interface Fiber Transceivers shall be easily replaceable. *Comments: Maintenance. Speed variability and flexibility capability.*	Design Decision
MIB Ethernet Precision Time Protocol (PTP)	MCH0105	The MIB shall use PTP for Time Synchronization. Network Interface Cards (NIC) or Ethernet Hardware PTP enabled.	[AD27]
MIB OPC-UA Server	MCH0106	The MIB shall support an Open Platform Communication Unified Architecture (OPC-UA) Server.	[AD27]
MIB Asynchronous Serial Interfaces	MCH0107	The MIB shall be capable of supporting Asynchronous Serial Interfaces to Devices or LRU.	SYS3101
MIB Synchronous Serial Interfaces	MCH0108	The MIB shall be capable of supporting Synchronous Serial Interfaces to Devices or LRU.	SYS3101
MIB Parallel Interface	MCH0109	The MIB shall be capable of supporting Parallel Interfaces to Devices or LRU. *Comment: (Bit, Byte, Word, Double-Word, etc.)*	SYS3101
MIB Identification	MCH0110	The MIB shall provide its Identification over the network.	ETR0403
MIB Remote Reset	MCH0111	The MIB shall provide a means to be reset from a remote external source. *Comments: A soft reboot does not qualify, as the target MIB may not be online to respond to the soft reboot request. However, this does not preclude the existence of a soft reboot or other indirect methods such as LRU power off/on controls.*	ETR0909

Parameter	Req. #	Value	Traceability
MIB Remote Device or LRU: Reset	MCH0112	The MIB shall provide the MIB Remote Reset to Devices or LRU.	ETR0909
MIB Local Device or LRU: Reset	MCH0113	The MIB shall provide a local reset for Devices or LRU.	ETR0909
MIB Remote Programmability	MCH0114	The MIB shall provide means to be re-programmed remotely. *Comments: This includes MIB programmable hardware elements such as FPGA, Flash Memory, EEPROM, etc. Exceptions are MIB identification features and other features (Bootloader, BIOS, RTOS) that must remain locked.*	ETR0907
MIB Firmware	MCH0115	All MIB programmable devices shall have a local copy of their firmware.	ETR0906
MIB Device or LRU: Integration	MCH0116	The MIB and M&C HIL subassemblies shall be integrated into Line Replaceable Units (LRUs)	ETR0301
MIB Device or LRU: Integrated Identification	MCH0117	The MIB and M&C HIL subassemblies that are integrated into Line Replaceable Units (LRUs) shall provide means for LRU Identification.	ETR0403
MIB Device or LRU: Non-Integrated Identification	MCH0118	The MIB and M&C HIL subassemblies that are not integrated into Line Replaceable Units (LRUs), but are externally connected to an LRU shall provide means for LRU Identification.	ETR0404
MIB Device or LRU: Programmability	MCH0119	The MIB shall provide means to re-program Devices or LRU. *Comments: This includes microprocessors and programmable hardware elements such as FPGA, Flash Memory, EEPROM, etc. Exceptions are Device identification features and other Device features (Bootloader, BIOS, RTOS, etc.) that must remain locked.*	ETR0907
MIB Network Location	MCH0120	The MIB shall identify its Network Location after power-on or reset.	CSS6031
MIB Configuration	MCH0121	The MIB shall configure itself and its Devices (LRU's) to become operationally ready and begin monitoring within 30 seconds.	CSS6031, ETR0811
MIB Automatic Reconfiguration	MCH0122	The MIB and associated LRU shall tell the M&C System that it is online. *Comment: This allows the M&C System to detect that an LRU has been replaced (or not) in order for the System to automatically reconfigure in any case for that specific LRU in a specific location.*	CSS6034

Parameter	Req. #	Value	Traceability
MIB Low Level Access	MCH0123	The MIB shall provide Low Level Access to the M&C System supporting troubleshooting.	CSS6035
MIB Watchdog Timer	MCH0124	The MIB shall utilize Watchdog timers for Software self-recovery. *Comment: Exceptions are COTS as MIB Devices only if the COTS device is not equipped with that feature.*	ETR0908
MIB Power Supervisors	MCH0125	The MIB shall utilize Power Supervisors for Power-Loss self-recovery. *Comment: Exceptions are COTS as MIB Devices only if the COTS device is not equipped with that feature.*	ETR0908
MIB Power Supply	MCH0126	The MIB shall be provided +5VDC ±10% Power. Rationale: Most digital designs still utilize +5VDC as Input Power. *Comment: Current is TBD until design efforts are complete. Estimated current: 1.0A ≤ I < 5.0A*	ETR0821, ETR0823
M&C HIL Analog Support	MCH0127	The M&C HIL shall support Analog Sampling at the MIB and/or at the LRU. *Comment: Target Capability: Sixteen Analog Channels.*	CSS6038
M&C HIL Low-Speed Sampling-Analog: System	MCH0128	The M&C HIL shall provide analog data to system (screens, archive, etc.) *Comment: Target capability: ±10V span; ≥12 bits; <500 kHz*	SYS3101
M&C HIL Simultaneous Analog Sampling	MCH0129	The M&C HIL shall support Low-Speed sampling System (screens, archive, etc.) simultaneously with High-Speed sampling for Maintenance (Oscilloscope)	CSS6038
M&C HIL High-Speed Sampling-Analog: Maintenance	MCH0130	The M&C HIL shall provide analog data (recorded) for maintenance. *Comment: Target capability: 2 Channels; ≥ ±2V span; ≥ 8 bits; ≥ 1 MHz*	CSS6038
M&C HIL Digital to Analog Capability	MCH0131	The M&C HIL shall provide Digital to Analog capability for Analog Signals to Devices or LRU. *Comment: Target capability: 2 Channels; ±10V span; ≥8bits*	CSS6038
M&C HIL Digital Logic Sampling	MCH0132	The M&C HIL shall provide logic analyzer capabilities for Digital Signals. *Comments: Target capability: 16bits; ≥100 MHz sampling. Applicable for bench maintenance or other maintenance situations.*	CSS6038
M&C HIL Software Tools	MCH0133	All Software tools for M&C HIL shall be chosen by and is the responsibility of Monitor and Control – Electronics. Comment: RTOS, Compilers, Embedded Processor Assemblers, FPGA Development Tools, Integrated Development Environment (IDE) tools, etc.	[AD08] [AD09]

Parameter	Req. #	Value	Traceability
M&C HIL PCB's	MCH0134	M&C HIL PCBs shall follow all PCB requirements per [AD10]. *Comment: Exception: COTS PCBs.*	[AD10]
M&C HIL Soldering and Electrical Connections	MCH0135	M&C HIL soldering and electrical connections shall follow Class 2 of the IPC-STD-J-001G requirements for Soldered Electrical and Electronic Assemblies.	ETR1301
M&C HIL Static Discharge Protection	MCH0136	All M&C HIL Electronics shall be designed to prevent build-up or dissipate electrostatic charge.	ETR0504
M&C HIL ESD Testing	MCH0137	All M&C HIL Electronics shall be tested for ESD susceptibility and classified. *Comment: Exception COTS*	ETR0501, ETR0505, ETR0506
M&C HIL ESD Workspace	MCH0138	All M&C HIL Electronics work efforts shall be at an ESD protected workspace	ETR0502
M&C HIL Packing, Storage, and Shipping	MCH0139	All M&C HIL Electronics shall be packed, stored, and shipped in approved ESD Protective Packaging.	ETR0503

8.3 Monitor and Control - Electronics LRU Functional Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Physical Marking	MCH0201	All Monitor and Control – Electronics Devices or LRU shall be marked with a physical label following standard MIL-STD-13231, and in addition its unique Part Number.	ETR0401
Monitor and Control – Electronics Devices or LRU: Physical Label Durability	MCH0202	All Monitor and Control – Electronics Devices or LRU. All physical labels shall be durable following standard MIL-DTL-15024.	ETR0409
Monitor and Control – Electronics Devices or LRU: Weight Label	MCH0203	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label indicating weight in pounds (lb).	ETR0406
Monitor and Control – Electronics Devices or LRU: Cable Labels	MCH0206	All Monitor and Control – Electronics Devices or LRU: Cables shall be labeled in accordance with ANSI Standard TIA-606-C when appropriate.	ETR1102

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Connector Labels	MCH0207	All Monitor and Control – Electronics Devices or LRU: Connectors shall be labeled in accordance with ANSI Standard TIA-606-C when appropriate.	ETR1134
Monitor and Control – Electronics Devices or LRU: Disconnect Label	MCH0208	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating to disconnect power to the LRU before any work takes place.	ETR0410
Monitor and Control – Electronics Devices or LRU: High Voltage Label	MCH0209	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating >50VDC or >50VAC rms is present.	ETR1008
Monitor and Control – Electronics Devices or LRU: Battery Label	MCH0210	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating a battery is present and a place for the install date. *Comment: For COTS. Avoid COTS Devices with Batteries.*	ETR1009
Monitor and Control – Electronics Devices or LRU: Power Switch Label	MCH0211	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating a power switch existence and location. *Comment: Off/On marking on switch or on label.*	ETR1010
Monitor and Control – Electronics Devices or LRU: Safety Ground Label	MCH0213	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating a safety ground existence and location. *Comment: Label and Ground Connection/Wire color is Green.*	ETR1012
Monitor and Control – Electronics Devices or LRU: Hazardous Warning Label	MCH0214	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating the meaning of a Hazardous Condition or Operation. *Comment: Mainly for equipment going into motion.*	ETR1013
Monitor and Control – Electronics Devices or LRU: Safety Instructions Label	MCH0215	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate critical safety instructions for removal, interactions, and/or installation.	ETR1014

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Arc Flash Label	MCH0216	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating a possibility for generating an arc flash.	ETR1015
Monitor and Control – Electronics Devices or LRU: Optical Safety Design	MCH0217	All Monitor and Control – Electronics Devices or LRU using Lasers or High Intensity LEDs at levels ANSI Z136 defined as dangerous shall be designed to minimize and/or prevent human exposure.	ETR1018
Monitor and Control – Electronics Devices or LRU: Optical Safety Label	MCH0218	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating the existence of Lasers. Labels will be in accordance with IEC 60825-1:2014 Standard at the time of Final Design Review.	ETR1019
Monitor and Control – Electronics Devices or LRU: Electrical and Optical Safety Standards	MCH0219	All Monitor and Control – Electronics Devices or LRU Electrical and Optical Standards shall be compliant with the applicable standard at the time of Final Design Review.	ETR1016
Monitor and Control – Electronics Devices or LRU: Tracking	MCH0220	All Monitor and Control – Electronics Devices or LRU shall have a Tracking Label and/or Device following standard MIL-P-19834 at the time of Final Design Review.	ETR0402
Monitor and Control – Electronics Devices or LRU: Identification	MCH0221	The Monitor and Control – Electronics Devices or LRU shall provide Identification.	ETR0403
Monitor and Control – Electronics Devices or LRU: Parameters	MCH0222	The Monitor and Control – Electronics Devices or LRU shall provide Parameters such as calibration, as defined in each LRU ICD. *Comment: These appears to indicate Plug and Play. That is, all information pertinent to a Device or LRU is stored at the Device or LRU, including specific information by LRU Serial Number such as calibration parameters.*	SYS3224, SYS3603
Monitor and Control – Electronics Devices or LRU: Firmware	MCH0223	All Monitor and Control – Electronics Devices or LRU programmable devices shall have a local copy of their firmware. *Comments: Storing at the MIB inside a LRU should suffice. However, an LRU without a MIB, or linked to a MIB is at the Supervisor.*	ETR0906

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Monitoring	MCH0224	Each Monitor and Control – Electronics Devices or LRU shall provide on-board monitoring and diagnostics to determine the health and status of the unit.	CSS6036
Monitor and Control – Electronics Devices or LRU: Alerts	MCH0225	When a Monitor and Control – Electronics Devices or LRU is out of specification, it shall generate a prioritized alert for processing by the operator and maintenance scheduler.	CSS6036
Monitor and Control – Electronics Local Devices or LRU: Maintenance Modes	MCH0226	Monitor and Control – Electronics Local Maintenance modes shall be available for local engineering diagnostics. *Comment: i.e. an on-board oscilloscope function.*	CSS6038
Monitor and Control – Electronics Remote Devices or LRU: Maintenance Modes	MCH0227	Monitor and Control – Electronics Remote Maintenance modes shall be available for remote engineering diagnostics. *Comment: i.e. an on-board oscilloscope function.*	CSS6038
Monitor and Control – Electronics Devices or LRU: Display Power Control	MCH0228	All Monitor and Control – Electronics Devices or LRU. Displays shall be capable of being turned off during operations and/or remotely. *Comment: Consider Power Off Cover Switch on LRU Mechanical Design.*	EMC0326
Monitor and Control – Electronics Devices or LRU: PCB's	MCH0229	The Monitor and Control – Electronics LRU PCBs shall follow all PCB requirements per [AD10]. *Comment: Exception COTS PCBs.*	[AD10]
Monitor and Control – Electronics Devices or LRU: Soldering and Electrical Connections	MCH0230	The Monitor and Control – Electronics LRU soldering and electrical connections shall follow Class 2 of the IPC-STD-001G requirements for Soldered Electrical and Electronic Assemblies at the time of Final Design Review.	ETR1301
Monitor and Control – Electronics Devices or LRU: PCB ESD Testing	MCH0231	All Monitor and Control – Electronics PCB's shall be tested for ESD susceptibility and classified. *Comment: Exception: COTS.*	ETR0501, ETR0505, ETR0506
Monitor and Control – Electronics Devices or LRU: Over Current Protection	MCH0232	All Monitor and Control – Electronics Devices or LRU shall implement Overcurrent Protection.	ETR0805
Monitor and Control – Electronics Devices or LRU: Over Current Protection Monitoring	MCH0233	All Monitor and Control – Electronics Devices or LRU shall implement overcurrent protection Monitoring. *Comment: Exception: When the protection device disables the LRU M&C Interface.*	ETR0806

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Thermal Protection	MCH0234	All Monitor and Control – Electronics Devices or LRU shall be thermally protected.	ETR0807
Monitor and Control – Electronics Devices or LRU: Thermal Protection Monitoring	MCH0235	All Monitor and Control – Electronics Devices or LRU shall implement thermal protection monitoring. Exception: When the protection device disables the LRU M&C Interface.	ETR0808
Monitor and Control – Electronics Devices or LRU: Thermal Analysis	MCH0236	All Monitor and Control – Electronics Devices or LRU shall analyze thermal performance and optimize for best performance.	ETR0816
Monitor and Control – Electronics Devices or LRU: Reset and or Startup	MCH0237	All Monitor and Control – Electronics Devices or LRU shall be able to be started or shutdown locally without intervention by Operations. *Comment: Even in the event of no M&C communications.*	ETR0809
Monitor and Control – Electronics Devices or LRU: Power Outages	MCH0238	All Monitor and Control – Electronics Devices or LRU shall enact a managed sequenced shutdown procedure to a safe standby state. *Comments: M&C Supervisory may trigger the event. In the case of no M&C communications where appropriate the LRU can automatically enact this procedure.*	ETR0810
Monitor and Control – Electronics Devices or LRU: Light Sources	MCH0239	All Monitor and Control – Electronics Devices or LRU Light Sources shall be long-life LED and/or OLED type devices.	ETR1148
Monitor and Control – Electronics Devices or LRU: LED Brightness	MCH0240	All Monitor and Control – Electronics Devices or LRU LED Brightness shall be at the minimum current required for their function.	ETR1153
Monitor and Control – Electronics Devices or LRU: Power Indicators	MCH0241	All Monitor and Control – Electronics Devices or LRU. Power Indicators shall be Blue LED marked as to Voltage. *Comment: Steady Blue = Normal; Blinking Blue = Out of Specification.*	ETR0812, ETR1149
Monitor and Control – Electronics Devices or LRU: Fault or Warning Indicators	MCH0242	All Monitor and Control – Electronics Devices or LRU. Fault or Warning Indicators shall be Red LED marked as to Fault or Warning. *Comment: Steady Red = Fault; Blinking Red = Warning.*	ETR1150

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Illumination	MCH0243	All Monitor and Control – Electronics Devices or LRU. Illumination shall be White LED to physically illuminate an area for purposes of maintenance or repair.	ETR1151
Monitor and Control – Electronics Devices or LRU: Status Indicators	MCH0244	All Monitor and Control – Electronics Devices or LRU. Status Indicators shall be Yellow or Green LED marked as to Status. *Comment: Green = Lock, Linked, etc.; Yellow = Activity.*	ETR1152
Monitor and Control – Electronics Devices or LRU: Batteries	MCH0245	All Monitor and Control – Electronics Devices or LRU shall not contain batteries. *Comments: Exception COTS Devices. Avoid COTS Devices with Batteries.*	ETR0817
Monitor and Control – Electronics Devices or LRU: Transient Protection	MCH0246	All Monitor and Control – Electronics Devices or LRU shall have Transient Voltage Suppression devices for external analog or digital I/O signals. *Comment: Exception is when suppression would negatively affect signal.*	ETR0818
Monitor and Control – Electronics Devices or LRU: ESD Workspace	*MCH0247*	*All Monitor and Control – Electronics Devices or LRU. Work efforts shall be at an ESD protected workspace.*	ETR0502
Monitor and Control – Electronics Devices or LRU: Static Discharge Protection	*MCH0248*	*All Monitor and Control – Electronics Devices or LRU shall be designed to prevent build-up or dissipate electrostatic charge.*	ETR0504
Monitor and Control – Electronics Devices or LRU: Software	*MCH0249*	All Software for Monitor and Control - Electronics Devices or LRU shall be the responsibility of Monitor and Control – Electronics. *Comment: Exception is Devices or LRU at the Supervisory Layer.*	[AD08] [AD09]
Monitor and Control – Electronics Devices or LRU: AC Reset	MCH0250	All Monitor and Control – Electronics Devices or LRU. AC powered shall be connected to a Power Distribution Unit for AC power cycling.	ETR0912
Monitor and Control – Electronics Devices or LRU: Self-Tests	MCH0251	All Monitor and Control – Electronics Devices or LRU shall perform self-testing at power-on safe state and then periodically afterwards. *Comments: Duration per ICD; Results to M&C System. Exception is COTS Devices.*	ETR0910
Monitor and Control – Electronics Devices or LRU: Advanced Diagnostics	MCH0252	All Monitor and Control – Electronics Devices or LRU shall be capable to perform advanced diagnostics by request.	ETR0911

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: AC Wiring Colors	MCH0253	All Monitor and Control – Electronics Devices or LRU. AC wiring colors shall conform to US NEC.	ETR1124
Monitor and Control – Electronics Devices or LRU: DC Discrete Wiring Colors	MCH0254	All Monitor and Control – Electronics Devices or LRU. Discrete wiring shall follow wiring colors per [AD10]	ETR1103 through ETR1123, ETR1154, ETR1155
Monitor and Control – Electronics Devices or LRU: Wiring Insulation	MCH0255	All Monitor and Control – Electronics Devices or LRU. Wiring Insulation shall utilize Irradiated PVC certified to meet UL 1430 specification rated at 300VDC over Temperature Range: $-55°C \leq T \leq 105°C$	ETR1157
Monitor and Control – Electronics Devices or LRU: Flexible Cables	MCH0256	All Monitor and Control – Electronics Devices or LRU. Cables that repeatably bend or have small bend radii shall utilize materials specifically designed for this purpose.	ETR1130
Monitor and Control – Electronics Devices or LRU: Bend Radius	MCH0257	All Monitor and Control – Electronics Devices or LRU. The minimum bend radius of all cables is set by the factory specifications for the cable.	ETR1131
Monitor and Control – Electronics Devices or LRU: Bend Radius Control	MCH0258	All Monitor and Control – Electronics Devices or LRU. The minimum bend radius for cables that need to move or flex shall be maintained by mechanical means.	ETR1189
Monitor and Control – Electronics Devices or LRU: Connector Current Rating	MCH0259	All Monitor and Control – Electronics Devices or LRU. Connector Current Rating shall follow single pin current limits. *Comment: Multiple pins being utilized for increased current rating is not allowed.*	ETR1135
Monitor and Control – Electronics Devices or LRU: Connector Environmental Rating	MCH0260	All Monitor and Control – Electronics Devices or LRU. Connector Environmental Rating shall be utilized in accordance with their designed environments.	ETR1136
Monitor and Control – Electronics Devices or LRU: Connector Mating Cycle Rating	MCH0261	All Monitor and Control – Electronics Devices or LRU. Connector Mating Cycle Rating shall follow the specified data sheet rating.	ETR1137

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Connector Hot Swapping	MCH0262	All Monitor and Control – Electronics Devices or LRU. Connector Hot Swapping shall have pins or sockets designed for this application.	ETR1138
Monitor and Control – Electronics Devices or LRU: Connector Hot Swapping Safety	MCH0263	All Monitor and Control – Electronics Devices or LRU. Connectors for Hot Swapping shall avoid contact arcing, abnormal current flow, and sequencing issues. *Comment: Long Pin Lengths is a technique to provide power sequencing, typically connecting grounds first before power and signals to avoid damaging electronics when hot swapping.*	ETR1139
Monitor and Control – Electronics Devices or LRU: Unmated Connector Safety	MCH0264	All Monitor and Control – Electronics Devices or LRU. Unmated connectors shall not expose Power or live signals. *Comment: Female connectors even with the same part number can have unexposed or exposed connections due to manufacturing plant location.*	ETR1140
Monitor and Control – Electronics Devices or LRU: Connector (Non-RF) Keying	MCH0265	All Monitor and Control – Electronics Devices or LRU. Non-RF connectors that are similar or closely located shall be unique and/or keyed to prevent incorrect connections.	ETR1141
Monitor and Control – Electronics Devices or LRU: Connector (RF) Identification	MCH0266	All Monitor and Control – Electronics Devices or LRU. RF connectors that are similar or closely located shall be visually unique and/or identified to minimize incorrect connections.	ETR1185
Monitor and Control – Electronics Devices or LRU: Common Connectors	MCH0267	All Monitor and Control – Electronics Devices or LRU. Common connectors that are used repeatably across multiple devices shall have critical signals and/or all signal pinouts standardized.	ETR1142
Monitor and Control – Electronics Devices or LRU: Connector Alignment	MCH0268	All Monitor and Control – Electronics Devices or LRU. Connectors that are blind-mate and/or backplane shall utilize some mechanism to ensure alignment during installation and removal.	ETR1158
Monitor and Control – Electronics Devices or LRU: Connector High Insertion Force	MCH0269	All Monitor and Control – Electronics Devices or LRU. Connectors that have high insertion force shall be adequately supported during insertion and removal.	ETR1159

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Devices or LRU: Connector High Insertion Force Tooling	MCH0270	All Monitor and Control – Electronics Devices or LRU. Connectors that have high insertion force shall be equipped with tooling such as ejectors to aid in installation and removal. *Comments: Tools not specifically designed for this application are not allowed.*	ETR1160
Monitor and Control – Electronics Devices or LRU: Crimped Connections	MCH0271	All Monitor and Control – Electronics Devices or LRU. Connectors shall use crimped connections for wiring terminations whenever possible.	ETR1186
Monitor and Control – Electronics Devices or LRU: Crimped Connection Standard	MCH0272	All Monitor and Control – Electronics Devices or LRU. Connectors that utilize crimped connections shall be in accordance with procedures defined in IPC/WHMA-A-620 (IPC Requirements and Acceptance for Cable and Wire Harness Assemblies) for wire/cable preparation and connection crimping.	ETR1187
Monitor and Control – Electronics Devices or LRU: PCB Packing, Storage, and Shipping	MCH0273	All Monitor and Control – Electronics LRU PCB's shall be packed, stored, and shipped in approved ESD Protective Packaging.	ETR0503
Monitor and Control – Electronics Device or LRU: ESD Testing	MCH0274	The Monitor and Control – Electronics Device or LRU shall be tested for ESD susceptibility and classified. *Comment: Exception COTS*	ETR0501, ETR0505, ETR0506
Monitor and Control – Electronics Device or LRU: Packing, Storage, and Shipping	MCH0275	The Monitor and Control – Electronics Device or LRU shall be packed, stored, and shipped in approved ESD Protective Packaging.	ETR0503
Monitor and Control – Electronics Devices or LRU: PCB Packing, Surge Protection	MCH0276	All Monitor and Control – Electronics Devices or LRU. Exposed Power and signal lines to large potential gradients shall be protected by silicon avalanche diode at LRU entry points.	ETR1203
Monitor and Control – Electronics Devices or LRU: Mechanical Assembly Requirements	MCH0277	A Monitor and Control – Electronics Devices or LRU shall follow all other appropriate LRU Mechanical Assembly requirements per [AD10]	ETR1161 through ETR1184, ETR1190, ETR1191

8.4 Environmental Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Storage Temperature	MCH0301	All Monitor and Control – Electronics shall be capable to be stored within this temperature range: 0°C ≤ T ≤ 30°C	ENV0372
Monitor and Control – Electronics Storage Relative Humidity	MCH0302	All Monitor and Control – Electronics shall be capable to be stored within this relative humidity range: 10% ≤ RH ≤ 90%	ENV0373
Monitor and Control – Electronics Altitude Range	MCH0303	All Monitor and Control – Electronics shall be designed to operate at altitudes ranging from sea level to 2500m	ENV0351
Monitor and Control – Electronics General Vibration	MCH0304	All Monitor and Control – Electronics shall withstand persistent vibration. *Comment: Testing will be for 60 minutes at 0.015g²/Hz Power Spectral Density (PSD) 0.001Hz ≤ f ≤ 40Hz. At f > 40Hz; PSD = 0.0163-0.00003.23(f)*	ENV0531
Monitor and Control – Electronics Transportation Solar Exposure	MCH0305	All Monitor and Control – Electronics shall be transported safely at Solar Radiant Energy of 1200W/m². *Comment: Withstand full sun or require to be placed into an insulated carrier.*	ENV0381
Monitor and Control – Electronics Transportation Temperature	MCH0306	All Monitor and Control – Electronics shall be capable to be transported within this temperature range: -30°C ≤ T ≤ 60°C	ENV0382
Monitor and Control – Electronics Operating Temperature	MCH0307	All Monitor and Control – Electronics shall be capable to be Operated within this temperature range: -40°C ≤ T ≤ 85°C (Industrial)	Design Decision
Monitor and Control – Electronics Transport Shock Test	MCH0308	All Monitor and Control – Electronics LRUs packaged for transportation shall survive mechanical shock levels from handling as defined in the MIL-STD-810H Method 516.8 Logistic Transit Drop Test. *Comment: 26 Drops at 75cm height.*	ENV0582

8.5 Maintenance, Availability, and Reliability Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Component Sources	MCH0401	The Monitor and Control – Electronics shall use parts from reliable manufacturers, vendors, and distributors.	ETR0901
Monitor and Control – Electronics Component Library	MCH0402	The Monitor and Control – Electronics shall utilize NRAO approved Standardized Library Parts.	ETR0902
Monitor and Control – Electronics Component Environmental Specifications	MCH0402	The Monitor and Control – Electronics shall utilize components in accordance with their specified environmental specifications.	ETR0903
Monitor and Control – Electronics Reliability Analysis	MCH0403	The Monitor and Control – Electronics shall undergo reliability, availability, and maintainability analysis per MIL-HDBK-217F.	ETR0904
Monitor and Control – Electronics Robustness Analysis	MCH0404	The Monitor and Control – Electronics shall be subject to a robustness analysis.	ETR0905
Monitor and Control – Electronics Mean Time Between Failure	MCH0405	The Monitor and Control – Electronics shall have a MTBF of ≥100,000 Hours. *Comment: After 240 to 480 Hours of Burn-In.*	SYS2610
Monitor and Control – Electronics Maintenance	MCH0406	The Monitor and Control – Electronics shall provide a Maintenance system and/or subsystem at the antenna to route predictive maintenance and self-diagnosis data to the M&C System.	CSS7000
Monitor and Control – Electronics Supervisory	MCH0407	The Monitor and Control – Electronics shall provide a Supervisory system at the antenna for controlling the antenna, performance evaluation, calibration, and solving routine problems.	CSS7025
Monitor and Control – Electronics Engineering / Operations Console	MCH0408	The Monitor and Control – Electronics shall provide the required communication interface for antenna system and/or subsystem to route needed information for system status and to assist in real-time diagnosis for the scientific, engineering and technical staff.	CSS6001

Monitor and Control – Electronics Engineering Database	MCH0409	The Monitor and Control – Electronics shall record monitor data at variable rates for automated use by predictive maintenance programs and for direct inspection by scientific, engineering and technical staff.	CSS6038
Monitor and Control – Electronics Mean Time Between Failure	MCH0410	The Monitor and Control – Electronics shall have a MTTR of ≤3 Hours with a goal of ≤30 minutes.	SYS2610

The maintenance and reliability requirements of the HIL subsystem support the system level reliability requirements that limit total array operating cost. The allocation of subsystem reliability is done by allocating an Achieved Availability to subsystems, which is determined by Mean Time Between Maintenance (MTBM) and Mean Downtime, as defined in [RD04]. In the case of HIL, it is expected that preventive maintenance will not be needed, and therefore the Inherent Availability is specified for HIL, which is expressed as Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). The MTBF is the mean time between failures of any HIL component on a single antenna. The specified MTBF assumes a burn-in of 240 – 480 hours. The MTTR is the mean time taken to replace or repair a HIL component, assuming the maintenance team is on site and the failed item has been identified. A software failure for which the system can automatically recover is also excluded. "Failure" is defined as a condition that places the system outside of its performance specifications or into an unsafe state, requiring repair. For the M&C HIL, the MTBF must be high as this subsystem is the link between LRUs and the online control system.

A Reliability, Availability, Maintainability analysis shall be performed in order to locate weak design points and to determine whether the design meets the Maintenance and Reliability requirements. The project recommends applying the Parts Count Method for predicting system reliability as described in the MIL-HDBK-217F, but the designer may propose to use other methods. For non-electronic parts, the values of NPRD-95 [RD02] or data from manufacturers or other databases may be used. Another, more time consuming (and considered more accurate) method, the Parts Stress Analysis Prediction, is also described in MIL-HDBK-217F. This may be used if the result of the Parts Count Method does not comply with the Maintenance and Reliability requirements.

The ngVLA equipment will typically operate at an elevation of 2500 m above sea level, where temperature and pressure might decrease the MTBF relative to that at low elevations. These conditions shall be taken into specific account in the reliability prediction by using the environmental factor given in MIL-HDBK-217F. The analysis shall result in estimates of the Mean Time to Failures (MTTF) and Mean Time to Repair (MTTR), assuming that any scheduled preventive maintenance is performed.

8.6 Lifecycle Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Design Life	MCH0501	The Monitor and Control – Electronics shall have a design life of 30 years to support 20 years of operational lifetime.	SYS2801

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Life Cycle Optimization	MCH0502	The Monitor and Control – Electronics design shall minimize its lifecycle cost for 20 years of operation.	SYS2802
Monitor and Control – Electronics Sustainability	MCH0503	The Monitor and Control – Electronics sustainability and long-term environmental impact in any material or design trade study.	SYS2803

8.7 Safety Design Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Safety-Critical Operations	MCH0601	The All Monitor and Control – Electronics software shall not be responsible for safety-critical operations involving damage to personnel and/or equipment. *Comment: This includes programmable electronics such as FPGA's, CPLDs, etc.*	CSS6037, SAF1210
Monitor and Control – Electronics Safety Specification	MCH0602	All Monitor and Control – Electronics designs shall comply with all appropriate Level-1 System Safety Specifications [AD05].	SYS2700
Monitor and Control – Electronics Controls for Safe Operations	MCH0603	The Monitor and Control – Electronics shall be designed to allow manual shutoff commands. *Comment: The Monitor and Control – Electronics needs to know that a manual shut off has occurred in order to de-energize equipment to a safe status mode even if the shutoff is immediately removed.*	ETR0809
Monitor and Control – Electronics Safety Mitigation	MCH0604	The design of the Monitor and Control – Electronics shall incorporate the ngVLA hazard analysis and follow the prioritized safety practices in their proper order.	SAF0032
Monitor and Control – Electronics Subsystem Self-Monitoring	MCH0605	The Monitor and Control – Electronics shall provide the communication interface between the antenna electronic subassemblies and the control center for the purpose system state-of-health monitoring.	SAF0042, SYS2701
Monitor and Control – Electronics IT Security	MCH0607	The Monitor and Control – Electronics shall be designed and operated in accordance with current IT Security best practices as defined by NSF-funded Center for Trustworthy Scientific Infrastructure (https://trustedci.org) and the AUI Cyber Security Policy.	SYS2702

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics LRU Over-Current Protection	MCH0608	The Monitor and Control – Electronics shall monitor and report the status of over-current protection devices. *Comment: Exception is if an over-current device disconnects the Monitor and Control – Electronics Device.*	ETR0806
Monitor and Control – Electronics LRU/Device Thermal Protection	MCH0609	The Monitor and Control – Electronics shall monitor and report the thermal status of Devices. Comments: When a thermal measurement reaches and goes above the first limit, Monitor and Control – Electronics shall Alert Operations. When a second limit is reached, Monitor and Control – Electronics may power down or power off the Device. Exception is if a thermal protection device disconnects the Monitor and Control – Electronics Device. The Operating Temperature range of Monitor and Control – Electronics must exceed the thermal (Current Assumption <<85°C) second limit specification.	ETR0808

8.8 Monitor and Control – Electronics Electromagnetic Compatibility Requirements

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Self-Generated Spurious Signal Power Level	MCH0701	The Monitor and Control – Electronics self-generated spurious signals shall not exceed EMC/RFI requirements per [AD04]. The overall goal is -135 dBm/BW ERIP at 10m from the receivers, over the specified bandwidth.	EMC0310 through EMC0312
Monitor and Control – Electronics Oscillators	MCH0702	All Monitor and Control – Electronics Oscillators shall be shielded. Comment: This includes using shielded enclosures and/or PCB Shielding techniques.	EMC0322
Monitor and Control – Electronics Clocked Devices	MCH0703	All Monitor and Control – Electronics Clocked Devices shall be shielded. Comments: This includes using shielded enclosures and/or PCB Shielding techniques. Also includes Data Clocks. Meant for Clocked A/Ds, D/As, FIFOs, etc.	EMC0322
Monitor and Control – Electronics Display Devices	MCH0704	Monitor and Control – Electronics Display Devices shall have Fully Enclosed Shields, including a display shield. *Comment: Consider Power Off Cover Switch on LRU Mechanical Design.*	EMC0326
Monitor and Control – Electronics Digital Devices or LRU: Shielding	MCH0705	Monitor and Control – Electronics Digital Devices or LRU shall be shielded with AC and/or DC power lines, and copper communication and/ or signal lines filtered at the chassis.	EMC0327
Monitor and Control – Electronics EMC/RFI Mitigation	MCH0706	All Monitor and Control – Electronics Devices shall be in compliance and tested per [AD04] and [AD10]	ETR0601

9 Documentation Generation and Storage Goals

9.1 Technical Documentation

All documentation related to the M&C HIL shall meet the following requirements:

- The language used for written documentation shall be English.
- Drawings shall be generated according to ISO standards and use metric units.
- Layouts of electronic circuits and printed circuit boards shall also be provided in electronically readable form. The ngVLA preferred formats are Altium Designer files for electronic circuit diagrams and printed circuit board layouts.
- The electronic document formats are Microsoft Word and Adobe PDF.
- The preferred CAD system used is AutoDesk Inventor and/or AutoCAD.

Any deviation from the above shall be agreed to by ngVLA.

Parameter	Req. #	Value	Traceability
Monitor and Control – Electronics Documentation	MCH0801	All Monitor and Control – Electronics Documentation shall be documented in accordance with ngVLA Documentation Standards.	SYS6001 through SYS6005
Monitor and Control – Electronics Cable Documentation	MCH0802	All Monitor and Control – Electronics wiring, cable, and harnesses shall be documented in accordance with ngVLA Documentation Standards.	ETR1101
Monitor and Control – Electronics Connector Documentation	MCH0803	All Monitor and Control – Electronics Connectors shall be documented in accordance with ngVLA Documentation Standards.	ETR1133

9.2 Software and Software Documentation

The M&C HIL software and any other specially developed software are deliverables. The software shall be delivered in source and object form, together with all procedures and tests necessary for compilation, installation, testing, upgrades, and maintenance.

Software must be tagged with suitable version numbers that allow identification (also online remotely) of a release. Software user manuals developed under this specification and for any other commercial software used (controller embedded software, special tools, etc.) shall be provided, along with software maintenance and installation upgrade documentation. Full Test and Acceptance procedures shall be documented.

10 Deleted Requirements

Parameter	Req. #	Value	Reason
Monitor and Control – Electronics Devices or LRU: Multiple Person Lift Label	MCH0204	All Monitor and Control – Electronics Devices or LRU weighing over 50lb. shall be marked with a visible physical label indicating Multiple Person Lift and the number of persons required to safely lift.	No M&C HIL equipment expected to weigh over 50lbs. (ETR0407)
Monitor and Control – Electronics Devices or LRU: Lift or Hoist Labels	MCH0205	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label indicating lift or hoist points.	No M&C HIL equipment expected to require hoisting. (ETR0408)
Monitor and Control – Electronics Devices or LRU: Emergency Cutoff Label	MCH0212	All Monitor and Control – Electronics Devices or LRU shall be marked with a visible physical label when appropriate indicating an emergency cutoff switch existence and location. *Comment: Label and Switch color is Red. Switch should require additional procedure to release. i.e. Easy to engage, slightly difficult to disengage.*	Utility Module Requirement, not a M&C HIL Requirement (ETR1011)

11 Verification

The design may be verified to meet the requirements by analysis (A), inspection (I), a demonstration (D), or a test (T), each defined below.

Verification by Analysis: The fulfillment of the specified performance shall be demonstrated by appropriate analysis (hand calculations, finite element analysis, thermal modeling, etc.), which will be checked by the ngVLA project office during the design phase.

Verification by Inspection: The compliance of the developed system is determined by a simple inspection or measurement.

Verification by Demonstration: The compliance of the developed feature is determined by a demonstration.

Verification by Test: The compliance of the developed system with the specified performance shall be demonstrated by site acceptance tests.

The following table summarizes the expected verification method for each requirement.

Req. #	Parameter/Requirement	A	I	D	T
MCH0101	MIB Ethernet Interface			*	
MCH0102	MIB Protocols			*	
MCH0103	MIB Ethernet Transceiver Interface				*
MCH0104	MIB Ethernet Transceiver Replaceability			*	
MCH0105	MIB Ethernet Precision Time Protocol (PTP)			*	
MCH0106	MIB Open Platform Communication Unified Architecture (OPC-UA) Server			*	
MCH0107	MIB Asynchronous Serial Interfaces			*	
MCH0108	MIB Synchronous Serial Interfaces			*	
MCH0109	MIB Parallel Interface			*	
MCH0110	MIB Identification			*	
MCH0111	MIB Remote Reset			*	
MCH0112	MIB Remote Device or LRU Reset			*	
MCH0113	MIB Local Device or LRU Reset			*	
MCH0114	MIB Remote Programmability			*	
MCH0115	MIB Firmware			*	
MCH0116	MIB Device or LRU Integration			*	
MCH0117	MIB Device or LRU: Integrated Identification			*	
MCH0118	MIB Device or LRU: Non-Integrated Identification			*	
MCH0119	MIB Device or LRU: Programmability			*	
MCH0120	MIB Network Location			*	
MCH0121	MIB Configuration			*	
MCH0122	MIB Automatic Reconfiguration			*	

Req. #	Parameter/Requirement	A	I	D	T
MCH0123	MIB Low Level Access			*	
MCH0124	MIB Watchdog Timer				*
MCH0125	MIB Power Supervisors				*
MCH0126	MIB Power Supply				*
MCH0127	M&C HIL Analog Support			*	
MCH0128	M&C HIL Low-Speed Sampling-Analog: System			*	
MCH0129	M&C HIL Simultaneous Analog Sampling			*	
MCH0130	M&C HIL High-Speed Sampling-Analog: Maintenance			*	
MCH0131	M&C HIL Digital to Analog Capability			*	
MCH0132	M&C HIL Digital Logic Sampling			*	
MCH0133	M&C HIL Software Tools	*			
MCH0134	M&C HIL PCB's			*	
MCH0135	M&C HIL Soldering and Electrical Connections			*	
MCH0136	M&C HIL Static Discharge Protection				*
MCH0137	M&C HIL ESD Testing				*
MCH0138	M&C HIL ESD Workspace	*			
MCH0139	M&C HIL Packing, Storage, and Shipping				*
MCH0201	M&C – Electronics Devices or LRU: Physical Marking			*	
MCH0202	M&C – Electronics Devices or LRU: Physical Label Durability				*
MCH0203	Deleted Requirement				
MCH0204	Deleted Requirement				
MCH0205	M&C – Electronics Devices or LRU: Lift or Hoist Labels			*	
MCH0206	M&C – Electronics Devices or LRU: Cable Labels			*	
MCH0207	M&C – Electronics Devices or LRU: Connector Labels		*		
MCH0208	M&C – Electronics Devices or LRU: Disconnect Label			*	
MCH0209	M&C – Electronics Devices or LRU: High Voltage Label		*		
MCH0210	M&C – Electronics Devices or LRU: Battery Label		*		
MCH0211	M&C – Electronics Devices or LRU: Power Switch Label		*		
MCH0212	M&C – Electronics Devices or LRU: Emergency Cutoff Label		*		
MCH0213	M&C – Electronics Devices or LRU: Safety Ground Label		*		
MCH0214	M&C – Electronics Devices or LRU: Hazardous Warning Label		*		
MCH0215	M&C – Electronics Devices or LRU: Safety Instructions Label		*		
MCH0216	M&C – Electronics Devices or LRU: Arc Flash Label			*	
MCH0217	M&C – Electronics Devices or LRU: Optical Safety Design	*			
MCH0218	M&C – Electronics Devices or LRU: Optical Safety Label				*
MCH0219	M&C – Electronics Devices or LRU: Electrical and Optical Safety Standards				*
MCH0220	M&C – Electronics Devices or LRU: Tracking			*	
MCH0221	M&C – Electronics Devices or LRU: Identification			*	
MCH0222	M&C – Electronics Devices or LRU: Parameters			*	
MCH0223	M&C – Electronics Devices or LRU: Firmware			*	

Req. #	Parameter/Requirement	A	I	D	T
MCH0224	M&C – Electronics Devices or LRU: Monitoring			*	
MCH0225	M&C – Electronics Devices or LRU: Alerts			*	
MCH0226	M&C – Electronics Local Devices or LRU: Maintenance Modes			*	
MCH0227	M&C – Electronics Remote Devices or LRU: Maintenance Modes			*	
MCH0228	M&C – Electronics Devices or LRU: Display Power Control			*	
MCH0229	M&C – Electronics Devices or LRU: PCB's			*	
MCH0230	M&C – Electronics Devices or LRU: Soldering and Electrical Connections			*	
MCH0231	M&C – Electronics Devices or LRU: PCB ESD Testing				*
MCH0232	M&C – Electronics Devices or LRU: Over Current Protection				*
MCH0233	M&C – Electronics Devices or LRU: Over Current Protection Monitoring				*
MCH0234	M&C – Electronics Devices or LRU: Thermal Protection				*
MCH0235	M&C – Electronics Devices or LRU: Thermal Protection Monitoring			*	
MCH0236	M&C – Electronics Devices or LRU: Thermal Analysis	*			
MCH0237	M&C – Electronics Devices or LRU: Reset and or Startup				*
MCH0238	M&C – Electronics Devices or LRU: Power Outages			*	
MCH0239	M&C – Electronics Devices or LRU: Light Sources			*	
MCH0240	M&C – Electronics Devices or LRU: LED Brightness			*	
MCH0241	M&C – Electronics Devices or LRU: Power Indicators			*	
MCH0242	M&C – Electronics Devices or LRU: Fault or Warning Indicators			*	
MCH0243	M&C – Electronics Devices or LRU: Illumination			*	
MCH0244	M&C – Electronics Devices or LRU: Status Indicators			*	
MCH0245	M&C – Electronics Devices or LRU: Batteries			*	
MCH0246	M&C – Electronics Devices or LRU: Transient Protection	*			
MCH0247	M&C – Electronics Devices or LRU: ESD Workspace	*			
MCH0248	M&C – Electronics Devices or LRU: Static Discharge Protection				*
MCH0249	M&C – Electronics Devices or LRU: Software	*			
MCH0250	M&C – Electronics Devices or LRU: AC Reset			*	
MCH0251	M&C – Electronics Devices or LRU: Self-Tests			*	
MCH0252	M&C – Electronics Devices or LRU: Advanced Diagnostics			*	
MCH0253	M&C – Electronics Devices or LRU: AC Wiring Colors			*	
MCH0254	M&C – Electronics Devices or LRU: DC Discrete Wiring Colors			*	
MCH0255	M&C – Electronics Devices or LRU: Wiring Insulation	*			
MCH0256	M&C – Electronics Devices or LRU: Flexible Cables	*			
MCH0257	M&C – Electronics Devices or LRU: Bend Radius			*	

Req. #	Parameter/Requirement	A	I	D	T
MCH0258	M&C – Electronics Devices or LRU: Bend Radius Control			*	
MCH0259	M&C – Electronics Devices or LRU: Connector Current Rating	*			
MCH0260	M&C – Electronics Devices or LRU: Connector Environmental Rating	*			
MCH0261	M&C – Electronics Devices or LRU: Connector Mating Cycle Rating	*			
MCH0262	M&C – Electronics Devices or LRU: Connector Hot Swapping	*			
MCH0263	M&C – Electronics Devices or LRU: Connector Hot Swapping Safety	*			
MCH0264	M&C – Electronics Devices or LRU: Unmated Connector Safety	*			
MCH0265	M&C – Electronics Devices or LRU: Connector (Non-RF) Keying			*	
MCH0266	M&C – Electronics Devices or LRU: Connector (RF) Identification			*	
MCH0267	M&C – Electronics Devices or LRU: Common Connectors	*			
MCH0268	M&C – Electronics Devices or LRU: Connector Alignment	*			
MCH0269	M&C – Electronics Devices or LRU: Connector High Insertion Force	*			
MCH0270	M&C – Electronics Devices or LRU: Connector High Insertion Force Tooling	*			
MCH0271	M&C – Electronics Devices or LRU: Crimped Connections			*	
MCH0272	M&C – Electronics Devices or LRU: Crimped Connection Standard			*	
MCH0273	M&C – Electronics Devices or LRU: PCB Packing, Storage, and Shipping				*
MCH0274	M&C – Electronics Device or LRU: ESD Testing				*
MCH0275	M&C – Electronics Device or LRU: Packing, Storage, and Shipping				*
MCH0276	M&C – Electronics Devices or LRU: PCB Packing, Surge Protection				*
MCH0277	M&C – Electronics Devices or LRU: Mechanical Assembly Requirements			*	
MCH0301	M&C – Electronics Storage Temperature	*			
MCH0302	M&C – Electronics Storage Relative Humidity	*			
MCH0303	M&C – Electronics Altitude Range	*			
MCH0304	M&C – Electronics General Vibration				*
MCH0305	M&C – Electronics Transportation Solar Exposure	*			
MCH0306	M&C – Electronics Transportation Temperature	*			
MCH0307	M&C – Electronics Operating Temperature				*
MCH0308	M&C – Electronics Transport Shock Test				*

Req. #	Parameter/Requirement	A	I	D	T
MCH0401	M&C – Electronics Component Sources	*			
MCH0402	M&C – Electronics Component Library	*			
MCH0402	M&C – Electronics Component Environmental Specifications	*			
MCH0403	M&C – Electronics Reliability Analysis	*			
MCH0404	M&C – Electronics Robustness Analysis	*			
MCH0405	M&C – Electronics Mean Time Between Failure	*			
MCH0406	M&C – Electronics Maintenance			*	
MCH0407	M&C – Electronics Supervisory			*	
MCH0408	M&C – Electronics Engineering / Operations Console			*	
MCH0409	M&C – Electronics Engineering Database			*	
MCH0410	M&C – Electronics Mean Time To Repair			*	
MCH0501	M&C – Electronics Design Life	*			
MCH0502	M&C – Electronics Life Cycle Optimization	*			
MCH0503	M&C – Electronics Sustainability		*		
MCH0601	M&C – Electronics Safety-Critical Operations	*			
MCH0602	M&C – Electronics Safety Specification	*			
MCH0603	M&C – Electronics Controls for Safe Operations			*	
MCH0604	M&C – Electronics Safety Mitigation			*	
MCH0605	M&C – Electronics Subsystem Self-Monitoring	*			
MCH0607	M&C – Electronics IT Security		*		
MCH0608	M&C – Electronics LRU Over-Current Protection				*
MCH0609	M&C – Electronics LRU/Device Thermal Protection				*
MCH0701	M&C – Electronics Self-Generated Spurious Signal Power Level				*
MCH0702	M&C – Electronics Oscillators	*			
MCH0703	M&C – Electronics Clocked Devices	*			
MCH0704	M&C – Electronics Display Devices			*	
MCH0705	M&C – Electronics Digital Devices or LRU: Shielding			*	
MCH0706	M&C – Electronics EMC/RFI Mitigation				*
MCH0801	M&C – Electronics Documentation			*	
MCH0802	M&C – Electronics Cable Documentation			*	
MCH0803	M&C – Electronics Connector Documentation			*	

Table 1 - Expected requirements verification method.

12 Appendix

12.1 Abbreviations and Acronyms

Acronym	Description
AD	Applicable Document
BIOS	Basic Input Output System
CDR	Critical Design Review
CoDR	Conceptual Design Review
CW	Continuous Wave (Sine wave of fixed frequency and amplitude)
EEPROM	Electrically Erasable Programmable Read Only Memory
EIRP	Equivalent Isotropic Radiated Power
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMP	Electromagnetic Pulse
FDR	Final Design Review
FEA	Finite Element Analysis
FOV	Field of View
FPGA	Field Programmable Gate Array
FWHM	Full Width Half Max (of Primary Beam Power)
HVAC	Heating, Ventilation & Air Conditioning
ICD	Interface Control Document
IF	Intermediate Frequency
JTAG	Joint Test Access Group
KPP	Key Performance Parameters
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LO	Local Oscillator
LRU	Line Replaceable Unit
M&C HIL	Monitor & Control Hardware Interface Layer
MIB	M&C HIL Interface Board (ngVLA context) Module Interface Board (VLA context)
MTBF	Mean Time Between Failure
MTTF	Mean Time to Failure
MTTR	Mean Time to Repair
ngVLA	Next Generation VLA
OPC UA	Open Platform Communication Unified Architecture
PDR	Preliminary Design Review
PTP	Precision Time Protocol
RD	Reference Document
RFI	Radio Frequency Interference
RMS	Root Mean Square
RSS	Root of Sum of Squares

Acronym	Description
RTOS	Real-Time Operating System
RTP	Round Trip Phase
SAC	Science Advisory Council
SNR	Signal to Noise Ratio
SRSS	Square Root Sum of the Square
SWG	Science Working Group
TAC	Technical Advisory Council
TBD	To Be Determined
VLA	Jansky Very Large Array

020.30.45.00.00-0002-REQ-MCHIL_PRELIM_TECH_REQS

Final Audit Report 2022-06-13

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"020.30.45.00.00-0002-REQ-MCHIL_PRELIM_TECH_REQS" History

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