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James Webb Space Telescope Project

Mission Requirements Document

October 17, 2007

JWST GSFC CMO

October 17, 2007

RELEASED

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

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

WAIVERS AND DEVIATIONS

Waivers and deviations against this document can be found in the NGIN library https://ngin.jwst.nasa.gov/ under this document record.

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JAMES WEBB SPACE TELESCOPE PROJECT

DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
Basic	Release Baseline version per JWST-CCR-000013	JB	11/27/2002
A	Released per JWST-CCR-000044	John Decker	5/14/2003
B	Released per JWST-CCR-000061	John Decker	6/30/2003
C	Released per JWST-CCR-000081	Phil Sabelhaus	9/30/2003
D	Released per JWST-CCR-000082R1 and JWST-CCR-000088	Phil Sabelhaus	11/17/2003
E	Released per JWST-CCR-000082R1 and JWST-CCR-000088	Phil Sabelhaus	11/17/2003
F	Released per JWST-CCR-000112	Phil Sabelhaus	3/4/2004
G	Released per JWST-CCR-000133	Phil Sabelhaus	3/24/2004
H	Released per JWST-CCR-000142	Phil Sabelhaus	5/3/2004
J	Released per JWST-CCR-000154	Phil Sabelhaus	9/9/2004
K	Released per JWST-CCR-000196	Phil Sabelhaus	12/06/2004
L	Released per JWST-CCR-000303	Phil Sabelhaus	5/26/2005
M	Released per JWST-CCR-000487	Phil Sabelhaus	3/22/2006
N	Released per JWST-CCR-000553	John Decker	8/4/2006
O	Skipped “O” Revision		
P	Released per JWST-CCR-000895	John Durning	9/28/2007

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date
1	3.7.1.7.4.0-2	Stray Light Radiance Requirements	P. Lightsey/ Ball	11/30/07
2	3.7.1.7.6.1	Need to resolve strehl ratio needed for moving targets as well as the definition of moving targets with NGST and SWG.	R. Lynch/ NASA	12/30/07
3	3.7.1.13.3	Need to resolve definition of moving targets and allowable total motion with NGST and SWG.	R. Lynch/ NASA	12/30/07

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1.0 SCOPE

1.1 PURPOSE

This Mission Requirements Document establishes the mission requirements for the James Webb Space Telescope (JWST). It allocates requirements to JWST segments, documents design constraints, and defines high level interface requirements between or among the JWST segments. The requirements specified in this document are valid during the pre-launch design phase, post-launch mission operations, and data analysis phases of the mission

1.2 PROJECT OBJECTIVES

The primary goal of the JWST is to observe the early universe, at an age between 1 million and a few billion years.

1.3 MISSION SCIENCE OBJECTIVES

JWST will be a space observatory capable of performing observations as defined in JWST Project Science Requirements Document (JWST-RQMT-002558).

1.4 INTERNATIONAL PARTNERSHIP

The National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the Canadian Space Agency (CSA) have a mutual interest in cooperating on the JWST mission. ESA and CSA may contribute science instruments, spacecraft hardware, ground system and/or operational support as part of this cooperation.

1.5 PRECEDENCE

This requirements document shall take precedence over lower-level requirements.

1.6 CHANGE CONTROL

Changes to this specification document shall be controlled using procedures set forth in the JWST Project Configuration Management Procedure (JWST-PROC-000654).

1.7 DOCUMENT ORGANIZATION

Section 1	specifies the purpose and content of this document. An overview of project and mission science objectives is included.
Section 2	lists reference documents.
Section 3	specifies the mission requirements levied upon the JWST system.
Section 4	contains the Verification Table.
Appendix A	contains Abbreviations and Acronyms
Appendix B	contains Traceability Matrix

2.0 REFERENCE DOCUMENTS

The following documents listed here were used as a reference for this document. Please refer to them for detailed information not included herein:

2.1 GODDARD SPACE FLIGHT CENTER DOCUMENTS

GEVS-STD-7000	General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects, April 2005
JWST-IRCD-000640	JWST ISIM to OTE and Spacecraft Interface Requirements and Control Document (IRCD)
JWST-IRD-003674	Application to Use Ariane (Demandé d'Utilisation Ariane [DUA]) Interface Requirements Document
JWST-OPS-002018	JWST Mission Operations Concept Document
JWST-PLAN-002028	JWST Observatory Contamination Control Plan
JWST-PLAN-000633	JWST Program Plan
JWST-PROC-000654	JWST Project Configuration Management Procedure
JWST-RQMT-002558	JWST Project Science Requirements Document

2.2 NON-GODDARD SPACE FLIGHT CENTER DOCUMENTS

IEEE/ASTM SI 10-2002	American National Standard for Use of the International System of Units (SI): The Modern Metric System
IEC 60027-2	International Electrotechnical Commission (IEC) International Standard

2.3 APPLICABLE DOCUMENTS

The following document forms a part of this specification to the extent specified herein. In the event of conflict between documents referenced and the detailed contents of this document, the requirements specified herein shall govern.

JWST-IRCD-000696	JWST Flight Observatory to Ground Segment Interface Requirements and Control Document (IRCD)
JWST-RQMT-004058	JWST Mechanisms Control Requirements

3.0 REQUIREMENTS

3.1 DEFINITION

3.1.1 System Constituents

The JWST system comprises the following segments and elements, with interrelationships depicted in the figure below:

1. The JWST Observatory is composed of the Spacecraft, Optical Telescope Element (OTE) and the Integrated Science Instrument Module (ISIM).
2. The Ground Segment is composed of the Science and Operations Center (S&OC), Institutional Systems and Common Systems.
3. The Launch Segment is composed of the Launch Vehicle, Payload Adapter and Launch Site Services.
4. The operational JWST System is composed of the JWST Observatory and the Ground Segment.

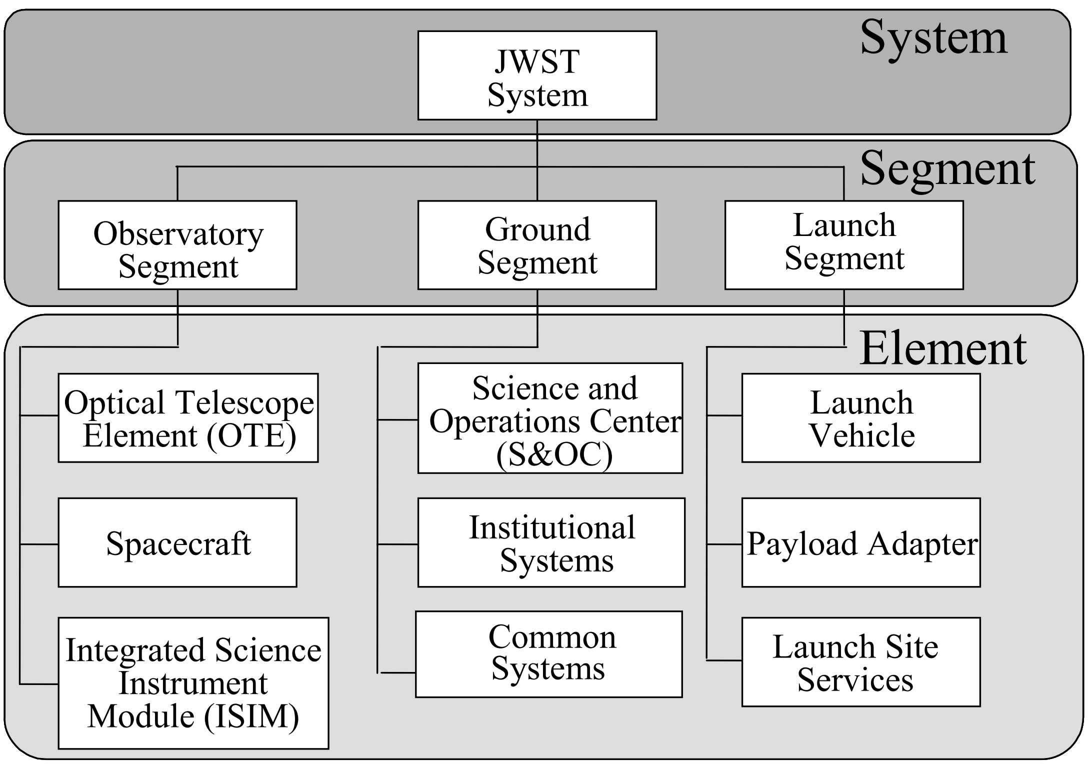

Figure 3-1. The JWST System

3.1.2 System Hierarchy

The following terminology is used within this document to describe the hierarchy of system constituents, from highest to lowest:

- System
  - Segment
    - Element
      - Subsystem
        - Component
          - Part

3.1.3 Glossary

Constraint	Activities or conditions, which are expected to cause permanent hardware damage; must not be violated.
Limitation	Activities, which will cause temporary loss of data, temporary degradation of components within the observatory, subsystem inconvenience, or loss of operating time
Restriction	Activities which are expected to cause irreversible degradation of hardware or instrument capabilities, or disruption in the Mission Schedule; may be violated with Mission Operations Manager approval.
Operational JWST System	The JWST system after the commissioning phase through the end of the mission.
Real-time system	The ground command and telemetry system.
Observing	The ability to point the Observatory at a specific location in the sky and take science data at that position while meeting all requirements.
Invalid command	Any command that has an undefined application identifier, bad checksum or undefined operation code.
Mean time to repair	The time from identification of the software repair item to its release to Operations.
Guide Star Acquisition	Acquiring a guide star and entering fine guidance on that star.
Emergency	An emergency is defined as any anomaly or onboard condition that requires immediate and unrestricted access to the Deep Space Network resources in order to prevent complete and imminent failure of the mission.
Event Driven Operations	An ordered sequence of operations steps that are executed based on the completion of the prior step.

Total sky coverage	The percentage of the celestial sphere that JWST can observe while meeting all performance requirements.
Field of Regard	The percentage of the celestial sphere that can be observed by the observatory at any given time while meeting all performance requirements.
Continuous visibility zone	The portion of the sky that is always within the field of regard of the Observatory
Damage	Any reduction in performance capability and/or lifetime beyond design limits.

3.1.4 Units

MR-92 The International System of Units shall be used per IEEE/ASTM SI 10-2002: American National Standard for Use of the International System of Units (SI): The Modern Metric System, with the following exceptions:

1) Hybrid SI/English units are permitted for engineering and manufacturing drawings.
2) Hybrid SI/standard astronomical units are permitted for Astronomer User's Manuals, user interfaces (Graphical User Interfaces and files) consistent with the Astronomer's User Manuals, and for the following project documents:

JWST-OPS-002018	JWST Mission Operations Concept Document
JWST-PLAN-000633	JWST Program Plan
JWST-RQMT-000634	JWST Project Mission Requirements Document
JWST-RQMT-002558	JWST Project Science Requirements Document

3) Non-SI units are permitted for heritage Ground Software.
4) Non-SI units are permitted in heritage hardware documentation
5) Per IEC 60027-2: International Electrotechnical Commission (IEC) International Standard the following SI prefixes are defined as follows:

Kilobit	1,000 bits.
Megabit	1,000,000 bits.
Gigabit	1,000,000,000 bits.

3.1.5 Orbit Coordinate System

The Orbit coordinate system axes are labeled X, Y, and Z and are shown in Figure 3-2. The primary +X axis originates from the Sun and points through the Earth to the L2 point. The +Y axis is in the ecliptic plane in the direction of the Earth orbital velocity about the sun. The +Z axis is along the resulting vector from the cross product of the +X and +Y axes (up out of page).

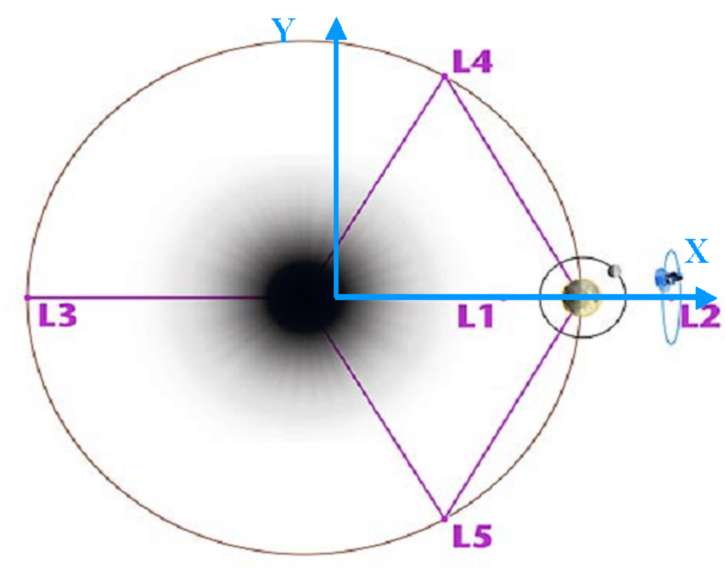

Figure 3-2. Orbit Coordinate System

3.1.6 Observatory Coordinate System

The Observatory coordinate system axes are labeled J1, J2, and J3. This system is a right-handed, observatory body fixed system, with its origin located at the center of the LV-to-Observatory interface ring. The J1 and J2 axes are on the interface plane, with the J1 axis pointing in the direction of the OTE boresight. The J3 axis is perpendicular to the LV-to-Observatory interface plane, with its positive direction oriented towards the Observatory. Figure 3-3 illustrates this system.

The OTE coordinate system axes are labeled V1, V2, and V3. The OTE origin (0, 0, 0) is at the vertex of the **nominal** primary mirror surface. The OTE axes are aligned with the Observatory axes, and the OTE coordinate system origin is offset from the Observatory origin as shown in Figure 3-3. The +V1 axis is perpendicular to the tangent plane of the primary mirror at its vertex. V1 is the ideal optical axis and is positive toward the secondary mirror. The +V3 axis points toward the single SMSS strut (the upper strut), such that the V1–V3 plane bisects the primary mirror (and three of its segments) along the primary mirror line of symmetry. The +V2 axis forms a righthanded system with the V1 and V3 axes. The V1–V2 plane also bisects the primary mirror along a line of symmetry.

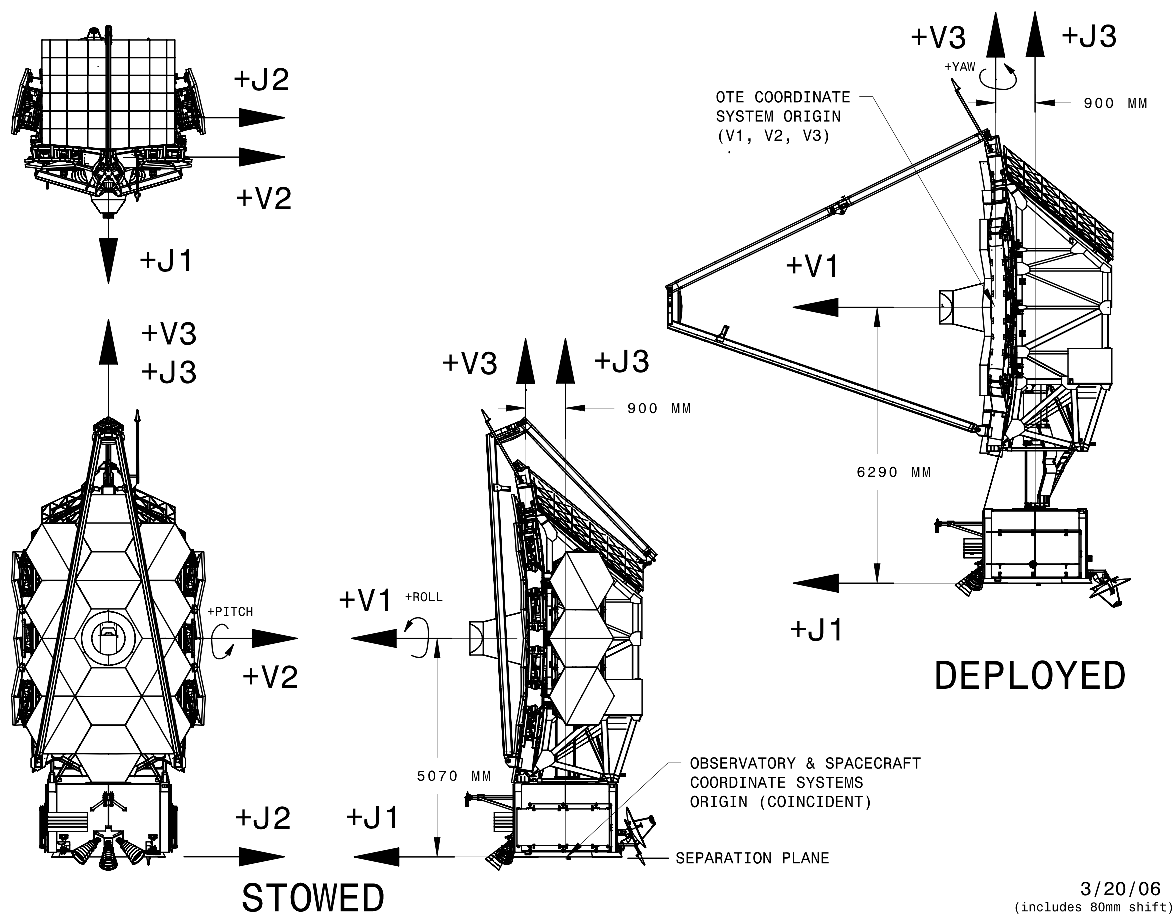

Figure 3-3. Observatory and OTE Coordinate Systems

3.2 SYSTEM CHARACTERISTICS

3.2.1 <u>Performance Characteristics</u>

3.2.1.1 Orbit

3.2.1.1.1 Transfer Orbit

MR-40 The Launch Vehicle shall place the Observatory on a trajectory from which the Observatory can transfer itself to its operational orbit.

3.2.1.1.2 Operational Orbit

MR-41 The Observatory shall orbit the Second LaGrange Point (L2) of the Sun–Earth system.

3.2.1.1.2.1 Orbit Maximum Z Excursion

MR-385 The operational JWST System shall maintain the excursion of the orbit about L2 in the Z direction (defined in Figure 3-2) to less than or equal to 500,000 Km.

3.2.1.1.2.2 Orbit Maximum Y Excursion

MR-386 The operational JWST System shall maintain the excursion of the orbit about L2 in the Y direction (defined in Figure 3-2) to less than or equal to 800,000 Km.

3.2.1.1.2.3 Eclipse Prevention

MR-387 The operational JWST System shall maintain the orbit about L2 such that the Observatory does not enter an eclipse.

3.2.1.1.3 Operational Orbit Transfer.

MR-42 After separation from the Launch Vehicle, the Observatory shall obtain its operational orbit about L2 from the Launch Vehicle transfer orbits defined in the Application to Use Ariane (DUA) IRD (JWST-IRD-003674).

3.2.1.2 Lifetime

3.2.1.2.1 Science Mission Lifetime

MR-44 The science mission lifetime, after commissioning, shall be a minimum of 5 years.

3.2.1.2.2 Commissioning Phase Duration

MR-45 The planned commissioning phase shall end no later than six months after launch.

3.2.1.3 Real-time Data Efficiency

MR-49 The operational JWST system shall deliver to the S&OC a minimum of 92.5% of all real-time telemetry.

3.2.1.4 Recorded Data Efficiency

MR-50 The operational JWST system shall archive a minimum of 97% of all data recorded on the Observatory.

3.2.1.5 Sensitivity

MR-51 The observatory system shall reach the sensitivity performance levels shown in the following table when observing a position on the celestial sphere that exhibits 1.2 times the minimum Zodiacal light background power as calculated in the NIRCam Sensitivity Calculations (JWST-CALC-003894), NIRSpec Sensitivity Calculations (JWST-CALC-003895), MIRI Sensitivity Calculations, (JWST-CALC-003896), and FGS-TF Sensitivity Calculations (JWST-CALC-003897).

Table 3-1. Sensitivity

Wavelength (µm)	Instrument / Mode	Sensitivity
1.15	NIRCam/WFS	1.10 x E^{-}31 Wm^{-2}Hz^{-1} SN=10 in 10.6 s or less and R=4 bandwidth
2	NIRCam	1.14 x E^{-}34 Wm^{-2}Hz^{-1} SN=10 in 10,000 s or less and R=4 bandwidth
3.5	FGS-TF	1.26 x E^{-}33 Wm^{-2}Hz^{-1} SN=10 in 10,000 s or less and R=100 bandwidth
3.0	NIRSpec/ Low Res	1.32 x E^{-}33 Wm^{-2}Hz^{-1} SN=10 in 10,000 s or less and R=100 bandwidth
2.0	NIRspec/ Med Res	5.72 x E^{-}22 Wm^{-2} SN=10 in 100,000 s or less
10	MIRI/ Broad-Band	7.0 x E^{-}33 Wm^{-2}Hz^{-1} SN=10 in 10,000 s or less and R=5 bandwidth
21	MIRI/ Broad-Band	8.7 x E^{-}32 Wm^{-2}Hz^{-1} SN=10 in 10,000 s or less and R=4.2 bandwidth
9.2	MIRI/ Spectrometer	1.0 x E^{-}20 Wm^{-2} SN=10 in 10,000 s or less and R=2400 bandwidth
22.5	MIRI/ Spectrometer	5.6 x E^{-}20 Wm^{-2} SN=10 in 10,000 s or less and R=1200 bandwidth

Note: The sensitivity at 1.15 micrometers is for WFS and is not derived from science requirements.

3.2.1.6 Contamination Control

MR-125 The contamination control of all Observatory components during fabrication, assembly, integration, and test shall be in accordance with the JWST Observatory Contamination Control Plan (JWST-PLAN-002028).

3.2.1.7 Pupil Imaging

MR-379 The JWST System shall image the OTE primary mirror to establish the optical alignment of the OTE to the NIRCam when commanded.

3.2.1.8 Downlink of Compressed Science Data Volume

MR-76 During a normal operations contact, the Observatory shall be capable of downlinking, and the Ground Segment capable of receiving 229 Gigabits of science data, which was compressed from 458 Gigabits.

3.2.1.9 Normal Operations

MR-77 The operational JWST System shall have at least one two-way communication contact between the Observatory and Ground Segment in a 24 hour period.

3.2.1.10 Continuous Two-way Communication

MR-78 The operational JWST System shall be in continuous two-way communication from separation from the upper stage of the launch vehicle until the completion of Observatory Primary Mirror Phasing activities.

3.2.1.11 Launch Phase Communications

MR-405 The operational JWST System shall be in downlink communication from launch vehicle payload fairing separation until separation from the upper stage of the launch vehicle.

3.2.1.12 Command Bit Error Rate

MR-79 The Observatory and Ground Segment combined command bit error rate (BER) shall be less than 1E-7 after applying physical layer decoding, not including retransmission by higher layers.

3.2.1.13 Telemetry Bit Error Rate

MR-80 The Observatory and Ground Segment combined telemetry BER for Ka-band and S-band downlink shall be less than 1E-7, after Reed-Solomon decoding corrections on the ground.

3.2.1.14 Nominal Data Quality

MR-381 The Observatory Data Loss shall be no more than 0.1% due to bit errors from each Science Instrument to transmission at the output of the spacecraft communication system.

3.2.1.15 Image-Based Wavefront Sensing and Control

MR-384 The JWST System shall perform image-based wavefront sensing and control to meet all image quality requirements.

3.2.1.16 Absolute Pointing Knowledge

MR-393 The operational JWST System shall determine the a posteriori pointing knowledge for the SI FOVs to within 1 arcsec (1-sigma, radial) of their true positions in the celestial coordinate frame. For imaging and spectroscopic data this applies over the entire SI FOV.

3.2.1.17 JWST System Efficiency

MR-102 After commissioning, the JWST system shall provide at least 30,556 hours of prime exposure time on scientific targets over 5 years. This is based on and will be verified by a hypothetical science program designed with 500, 90 degree slews and 8,000 small angle slews per year.

3.2.1.18 Field Distortion Uncertainty

MR-120 After calibration, the field distortion uncertainty within any SI and the guider shall not exceed 0.005 arcsec, 1 sigma per axis.

3.2.2 Physical Characteristics

3.2.2.1 Deep Space Network

MR-82 The operational JWST system shall utilize the Deep Space Network (DSN).

3.2.3 Reliability

3.2.3.1 Single Failure

MR-84 No single part failure shall cause total loss of a function, or prevent access to extant redundant functionality.

3.2.4 Maintainability

3.2.5 Environmental Conditions

3.3 DESIGN AND CONSTRUCTION

3.3.1 Thermal Design Margins

MR-90 Thermal design margins shall be in accordance with the General Environmental Verification Specification for STS and ELV Payloads, Subsystems and Components (GEVS-SE) for all non-cryogenic components.

3.3.2 Calculated Heat Rejection Capacity Margins for Cryogenic Systems

MR-91 The calculated margin on the heat rejection capacity of cryogenic systems shall be no less than 50% at the Critical Design Review (CDR). (This requirement does not apply to stored cryogen.) For all cryogenic components (<100 Kelvin [K]), margin is defined as excess heat rejection capacity as a percentage of the calculated load. Calculated load includes power dissipation and predicted radiative and conductive parasitics. Heat rejection capacity is calculated at the maximum allowable operating temperature. Excess capacity is defined as the rejection capacity minus the calculated load.

3.4 DOCUMENTATION

3.5 LOGISTICS

3.6 PERSONNEL AND TRAINING

3.7 CHARACTERISTICS OF SUBORDINATE SEGMENTS

3.7.1 Observatory Segment

3.7.1.1 Orbit

3.7.1.1.1 Orbit Range

MR-406 The Observatory shall operate up to a maximum Earth range of 1.8×10^6 kilometers.

3.7.1.1.2 Maximum Z Excursion

MR-388 The Observatory shall provide the delta velocity, as computed by the Ground Segment, to maintain the excursion of the orbit about L2 in the Z direction (defined in Figure 3-2) to less than or equal to 500,000 Km.

3.7.1.1.3 Orbit Maximum Y Excursion

MR-389 The Observatory shall provide the delta velocity, as computed by the Ground Segment, to maintain the excursion of the orbit about L2 in the Y direction (defined in Figure 3-2) to less than or equal to 800,000 Km.

3.7.1.2 Observatory Mass

3.7.1.2.1 Observatory Mass Allocation

MR-99 The JWST Observatory wet mass shall not exceed 6,159 kilograms.

3.7.1.2.2 Mission-Unique Launch Vehicle Accommodation

MR-100 Any launch vehicle performance enhancement or reduction due to mission-unique, non-standard launch vehicle hardware or capability shall be added or subtracted, respectively, from the Observatory mass allocation.

3.7.1.3 Observatory Overhead

MR-390 After commissioning, the JWST observatory shall use no more than 10,206 hours over 5 years for overhead activities which detract from prime exposure time on scientific targets. This allocation includes time for wavefront sensing and control activities, High Gain Antenna Steering, Observatory large, medium and small angle slew and settling times, station keeping, momentum management, spacecraft and ISIM safe mode down time, Guide Star identification, acquisition and retries, science instrument internal calibrations, and overheads associated with the set-up of science instrument for observations. The allocation is based on and will be verified by a hypothetical science program designed with 500, 90 degree slews and 8,000 small angle slews per year.

3.7.1.4 Celestial Sphere Coverage

3.7.1.4.1 Annual Coverage

MR-103 Over an interval of one sidereal year, the Observatory shall have total sky coverage of 100%. Total sky coverage is defined as the percentage of the celestial sphere that JWST can observe while meeting all performance requirements.

3.7.1.4.2 Field of Regard

MR-104 The Observatory Field of Regard shall be at least 35% of the celestial sphere. Field of Regard is defined as the percentage of the celestial sphere that can be observed by the observatory at any given time while meeting all performance requirements.

3.7.1.4.3 Consecutive Coverage

MR-105 The Observatory shall observe targets in 50% of the celestial sphere for at least 60 consecutive days per year, when commanded.

3.7.1.4.4 Continuous Visibility Zone

MR-106 The Observatory shall have a continuous visibility zone within 5 degrees of the ecliptic poles. Continuous visibility zone is defined as that portion of the sky that is always within the field of regard of the Observatory.

3.7.1.5 Wavelength Range

MR-107 The Observatory spectral coverage shall extend from 0.6 μm to 27 μm.

3.7.1.6 Reliability

3.7.1.6.1 Spacecraft and Optical Telescope Element Reliability

MR-368 The Spacecraft and OTE shall have a combined reliability goal of 0.920.

3.7.1.6.2 ISIM Reliability

MR-383 The reliability of the ISIM element shall be greater than or equal to .758.

3.7.1.7 Image Quality Requirements

The following optical performance requirements apply to the full optical system defined as the entrance pupil of the optics system to the final focal planes of the instruments, and include allowances for thermal and mechanical error sources. This includes line-of-sight stabilization and errors from vibration sources. Where a requirement is stated at a specific wavelength, that wavelength is the center wavelength of a flat bandpass filter with a resolution of R=4 (for wavelengths less than 5 μm) or R=5 (for wavelengths greater than 5 μm). A constant brightness (W m^{-2} Hz^{-1} units) target is assumed in all cases. Requirement values in this section are determined using these conditions.

3.7.1.7.1 Image Quality for Near-Infrared and Guider Focal Planes

3.7.1.7.1.1 Strehl Ratio

MR-110 Over the FOV of the NIRCam, the observatory shall be diffraction limited at 2 μm defined as having a Strehl Ratio greater than or equal to 0.8.

3.7.1.7.1.2 Encircled Energy Stability

3.7.1.7.1.2.1 24 Hour Encircled Energy Stability

MR-113 Without requiring ground-commanded correction, there shall be less than 2.0% root-mean-squared (RMS) variation about the mean encircled energy, defined to be at 0.08 arcsec radius at a wavelength of 2μm, over a 24 hour period.

3.7.1.7.1.2.1.1 Conditions

MR-114 The 24 hour stability requirements shall be met for any combination of target pointings within the field of regard (FOR), including those separated by a slew with a thermally worst-case 10 degree pitch change.

3.7.1.7.1.2.2 Encircled Energy Long Term Stability

MR-115 The Encircled Energy within a radius of 0.08 arcsec at 2 μm shall not change by more than 2.5% in less than 14 days following a worst case slew from a thermal equilibrium condition at the coldest pointing environment to the hottest pointing environment.

Note: The 14 days is given for the purpose of analysis.

3.7.1.7.2 Strehl Ratio for Mid-Infrared Instrument

MR-116 The Observatory, over the FOV of the Mid-Infrared Instrument (MIRI) shall be diffraction limited at 5.6 µm, defined as having a Strehl Ratio greater than or equal to 0.8.

3.7.1.7.3 Stray Light at Near-Infrared Wavelengths

MR-121 When observing a position on the celestial sphere that exhibits 1.2 times the minimum Zodiacal light background radiance, the stray light incident into an instrument acceptance cone at the instrument pickoff mirror shall be less than an equivalent background in the field of view having a spectral radiance at the wavelengths and exclusion angles given in the table below. Sources excluded from contributing to this stray light are [1] sources inside the exclusion angle of the nominal line-of-sight, [2] sources brighter than AB mag=1 within 2.5 degrees of the line-of-sight, [3] solar system planets other than the Earth-Moon system.

Table 3-2. Stray Light Radiance Requirements

Radiance (1×10^{-20} W/(m^2-Hz-sr))		**Exclusion Angle (degrees)**			
		1.0	0.50	0.25	0.10
Wavelength (micrometer)	2.0	0.091 (**TBR**)	0.044 (**TBR**)	0.061 (**TBR**)	0.598 (**TBR**)
	3.0	0.032 (**TBR**)	0.035 (**TBR**)	0.042 (**TBR**)	0.326 (**TBR**)

3.7.1.7.4 Stray Light From Thermal Emissions

MR-122 The thermal emission stray light from the Observatory incident into an instrument acceptance cone at the instrument pickoff mirror shall be less than an equivalent background in the field of view having a spectral radiance of 3.9 E-20 W m^{-2} Hz^{-1} sr^{-1} at a wavelength of 10 µm and 2.00 E-18 W m^{-2} Hz^{-1} sr^{-1} at a wavelength of 20 µm.

3.7.1.7.5 Image Quality for Moving Targets

This section delineates the list of optical requirements that shall be met when tracking moving targets. Unless specified in this section, all other optical requirements do not apply to moving targets. The optical requirement MR 371 shall be met when tracking moving targets.

3.7.1.7.5.1 Strehl Ratio For Moving Targets

MR-371 Over the FOV of the NIRCam, the Observatory shall be diffraction limited at 2 µm defined as having a Strehl Ratio greater than or equal to (To Be Determined [**TBD**]) when tracking any available target that exhibits an angular velocity v in the range of (**TBD**) milliseconds of arc per second (mas s^{-1}) with respect to the guide star.

3.7.1.8 Image Based Wavefront Sensing

MR-123 The Observatory shall perform image-based wavefront sensing when commanded.

3.7.1.9 Wavefront Error Correction Capability

MR-124 The Observatory wavefront error (WFE) shall be correctable via ground command.

3.7.1.10 Normal Operations

MR-391 After Observatory Primary Mirror Phasing activities are completed the Observatory shall communicate with the Ground Segment on a daily basis.

3.7.1.11 Command And Data Handling Subsystem

3.7.1.11.1 Observatory Event Logs

MR-127 The Observatory shall maintain event logs of the status of Observatory subsystems.

3.7.1.11.2 Command Authentication

MR-128 During normal operations, the Observatory shall reject commands that do not meet the authentication protocol specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.11.3 On-Board Storage

MR-129 All science and defined engineering and housekeeping data generated by JWST shall be written to on-board storage and held for downlink to the Ground Segment.

3.7.1.11.3.1 Storage Capacity

MR-130 The Spacecraft data storage capacity shall be at least 471 Gigabits of science and engineering data.

3.7.1.11.3.2 Identification of Data

3.7.1.11.3.2.1 Science Exposure Identification

MR-133 All science data common to a single exposure shall share a unique exposure identification by instrument that makes those data identifiable in on-board storage.

3.7.1.11.3.2.2 Science Observation Identification

MR-134 All science data common to an observation shall share a unique observation identification that makes those data identifiable in on-board storage.

3.7.1.11.3.3 Simultaneous Onboard Storage

MR-135 The Spacecraft shall simultaneously store onboard science and housekeeping (including engineering) data during data playback.

3.7.1.11.4 Common Data Bus, Point to Point, and Power Interfaces

MR-137 The Observatory internal Command and Data Handling interfaces shall be compatible in accordance with the JWST ISIM to OTE and Spacecraft IRCD (JWST-IRCD-000640).

3.7.1.11.5 Processor Utilization

MR-138 At launch, the processor usage required to support operations (launch, commissioning and post-commissioning) shall not exceed 70% peak processor usage of total processor throughput capability.

3.7.1.11.6 Local and External Data Bus Utilization

MR-139 The local and external data bus utilization required to support planned operations (launch, commissioning and post-commissioning) shall be no greater than 80% peak.

3.7.1.11.7 Timing

3.7.1.11.7.1 Coordinated Universal Time Correlation Accuracy

MR-142 The Observatory central timing system shall be correlated to Coordinated Universal Time (UTC) to the accuracy defined in the JWST Flight Observatory to Ground Segment Interface Requirements and Control Document (JWST-IRCD-000696).

3.7.1.11.7.2 Coordinated Universal Time Clock Maintenance

MR-143 The UTC clock correlation shall not require update more than once per day.

3.7.1.11.8 Commanding

3.7.1.11.8.1 Capability for Real-Time Commanding

MR-145 In conjunction with the on-going execution of stored commands, the Observatory shall have the capability to receive and execute real-time commands from the ground segment.

3.7.1.11.8.2 Prevention of Mutual Interference

MR-146 Protections shall exist to prevent the mutual interference of real–time and stored commanding.

3.7.1.11.8.3 Command Safety

MR-147 The Observatory shall remain safe in the event of any command error or break in a command sequence.

3.7.1.11.8.4 Command Verification

MR-148 The Observatory shall verify all commands received.

3.7.1.11.8.5 Report Verified Commands

MR-149 The Observatory shall report all verified commands.

3.7.1.11.8.6 Command Validation

MR-150 The Observatory shall validate all commands prior to execution.

3.7.1.11.8.7 Report Validated Commands

MR-151 The Observatory shall report all validated commands.

3.7.1.11.8.8 Report Executed Commands

MR-152 The Observatory shall report all commands that have been executed.

3.7.1.11.8.9 Command Rejection

MR-153 The Observatory shall report and reject invalid commands. An invalid command is any command that has an undefined application identifier, bad checksum or undefined operation code.

3.7.1.11.9 Operations

3.7.1.11.9.1 Parallel Operations

MR-156 The Observatory shall be capable of parallel SI exposures while performing fine guidance.

3.7.1.11.9.2 Autonomous Operation

MR-157 The Observatory C&DH hardware (except for the Solid State Recorder [SSR] storage capacity) and software shall be sized for 10 days of autonomous science plan execution without ground intervention.

3.7.1.11.9.3 Observatory Replan Accommodation

MR-158 The Observatory shall accommodate uplinked replans that revise the on-board science observation plan.

3.7.1.11.10 Onboard Data Management

3.7.1.11.10.1 Data Playback

MR-159 Concurrent with playback of stored data, the Spacecraft shall downlink real-time housekeeping (including real-time engineering) and ancillary data (e.g., memory dumps).

3.7.1.11.10.2 Interleave Real-time with Recorded Data

MR-375 When the Ka-band communication link is available, the real-time engineering data shall be interleaved with the recorded engineering and science data for transmission via the Ka-Band link.

3.7.1.11.11 Observatory Software

3.7.1.11.11.1 Event-Driven Observatory Operations

MR-161 The Observatory software shall execute event-driven Observatory operations.

3.7.1.11.11.2 Common Command and Data Handling Operating System

MR-162 The Observatory internal Command and Data Handling subsystems shall use the same Operating System.

3.7.1.11.11.3 Flight Software Common Programming Language

MR-163 Observatory software that is modifiable after launch shall be developed using commercially supported Ada, C, C++, or assembly programming language when use of a high level language will not meet performance requirements.

3.7.1.11.11.4 Software Maintenance

3.7.1.11.11.4.1 In-Flight Updates

MR-166 The Observatory shall continue uninterrupted science operations during real-time ground commanded changes to tables and files.

3.7.1.11.11.4.2 Volatile Memory Reloading

MR-392 All FSW that executes out of volatile memory (RAM and EEPROM type devices) shall be maintainable through partial and full reloading.

3.7.1.11.12 Memory Margin

MR-366 Any single processor with in-flight reconfigurable software shall maintain 30% volatile and non-volatile memory margin at launch.

3.7.1.11.13 Nominal Observatory Data Loss

MR-382 The Observatory data loss shall be no more than 0.1% due to bit errors from FPE data acquisition to transmission at the output of the Spacecraft communication system.

3.7.1.12 Pointing and Tracking

3.7.1.12.1 Sun Damage

MR-168 The Observatory shall prevent permanent damage to itself due to exposure to the Sun during all phases of the mission. Damage is defined as any permanent inability to meet performance requirements.

3.7.1.12.2 Guiding

3.7.1.12.2.1 Guiding Capability

MR-170 The Observatory shall use stars to stabilize the image on the detectors.

3.7.1.12.2.2 Guide Star Availability

MR-171 The Observatory shall have greater than 95% probability of acquiring a guide star and maintaining pointing stability on any fixed target for any valid attitude within the FOR.

3.7.1.12.2.3 Single Point Failure

MR-365 No single point failure in the Fine Guidance Sensor (FGS) shall reduce the probability of acquiring a guide star below 90%.

3.7.1.12.3 Moving Target Tracking

MR-372 When commanded the Observatory shall track targets which exhibit any angular velocity in the range of (**TBD**) milli-arseconds per second over a total motion (**TBD**) arcsec with respect to the guide star.

3.7.1.12.4 Observatory Optical Telescope Element Boresight Coarse Pointing Accuracy

MR-172 When commanded, the Observatory shall point the OTE boresight to an accuracy of better than or equal to 7 arcsec (1-sigma, per axis) without using the FGS or SIs. This is the maximum allowable difference in angle between the commanded pointing direction and the actual pointing direction in celestial coordinates. Boresight pointing axes are pitch and yaw. This requirement does not apply to roll around the boresight axis.

3.7.1.12.5 Fine Guidance Pointing Accuracy

MR-173 After entering fine guidance mode, the Observatory shall position a target within any SI FOV to an accuracy of 1 arcsec (1-sigma, radial) without using the SIs.

3.7.1.12.6 Relative Offset Pointing Repeatability

MR-174 During a 24 hour period of fine guidance, the Observatory shall, when commanded, remove or repeat a previous offset within a SI FOV with a repeatability of 5 milli-arcseconds, 1 sigma, per axis, regardless of the location of the guide star.

3.7.1.12.7 Science Instrument FOV Pointing Knowledge Data

MR-175 The Observatory shall collect and deliver the science and engineering data to the Ground Segment required to determine the SI FOVs a posteriori pointing knowledge.

3.7.1.12.8 Field Orientation Control

MR-176 The Observatory shall control the field of view orientation to less than or equal to 7 arcsec RMS.

3.7.1.12.9 Field of View Orientation

MR-177 The Observatory shall be sized to point the same orientation of its FOV for 10 days for any available fixed target. Breaks in the observation to perform housekeeping functions such as momentum unloading, etc. are allowed as long as the total FOV orientation time on the target is greater than or equal to 10 days.

3.7.1.12.10 Re-Pointing

MR-178 The Observatory shall complete a 90-degree slew in 60 minutes or less.

Note: This includes settling, guide star identification and acquisition time. The 60-minute period does not include momentum dumping.

3.7.1.12.11 Small Maneuver Slew Rate

MR-179 The Observatory shall complete a 20 arc-second offset in 60 seconds or less.

Note: This includes settling, guide star identification and acquisition time.

3.7.1.12.12 Medium Maneuver Slew Rate

MR-180 The Observatory shall complete a 280 arcsecond slew in 480 seconds or less.

Note: This includes settling, guide star identification and acquisition time.

3.7.1.12.13 Field of View Offsets, 0.0 - 0.5 Arcsec

MR-182 When commanded, the Observatory shall offset a science instrument FOV by 0.0 - 0.5 arcsec with an accuracy of 0.005 arcsec, 1 sigma, per axis, regardless of the location of the guide star.

3.7.1.12.14 Field of View Offsets, 0.5 – 2.0 Arcsec

MR-181 When commanded, the Observatory shall offset a SI FOV by 0.5 - 2.0 arcsec with an accuracy of 1 percent, 1 sigma, per axis, regardless of the location of the guide star.

3.7.1.12.15 Field of View Offsets, 2.0 - 20 Arcsec

MR-374 When commanded, the Observatory shall offset a SI FOV by 2.0 - 20 arcsec with an accuracy of 0.02 arcsec, 1 sigma, per axis, regardless of the location of the guide star.

3.7.1.12.16 Field of View Offsets, 20 - 45 Arcsec

MR-364 When commanded, the Observatory shall offset the MIRI FOV by 20 - 45 arcsec with an accuracy of 0.09 arcsec, 1 sigma, per axis in its focal plane, regardless of the location of the guide star.

3.7.1.13 Integrated Science Instrument Module

3.7.1.13.1 Integrated Science Instrument Module Mass

MR-184 The ISIM mass allocation shall be 1,505 kilograms (kg).

3.7.1.13.2 Integrated Science Instrument Module Average Power Allocation

MR-373 The ISIM average power allocation shall be 740 watts.

3.7.1.13.3 Science Instruments and Guiders Allocated Field of View

MR-369 The SIs and guiders allocated field of views shall be greater than or equal to the values shown in the table below:

Table 3-3. SIs and Guiders Allocated FOV

Instrument	Minimum Unvignetted FOV Allocation in OTE Focal Plane (arcmin)	Minimum Effective Science FOV in OTE Focal Plane (square arcmin)
NIRCam	2.3 x 2.3 for each of two modules	4.7 for each of two modules
NIRSpec	3.5 x 3.5	9.0
MIRI	2.4 x 2.4	3.5
FGS-TF	2.3 x 2.3	4.7
FGS-Guider	2.3 x 2.3 for each of two modules	NA

3.7.1.13.4 Science Instruments and Guiders Field of View

MR-370 The SIs and guiders FOVs shall be arranged in a non-overlapping fashion within the OTE FOV as defined in the ISIM to OTE and Spacecraft IRCD (JWST-IRCD-000640).

3.7.1.13.5 Imagery Spectral Resolution

MR-185 The Observatory shall provide imagery with spectral resolution (R) in the range of $3 < R < 200$ over a wavelength range of 0.6 - 27 µm.

3.7.1.13.6 Spectroscopy Spectral Resolution

MR-186 The Observatory shall provide spectroscopy with spectral resolution (R) in the range of $50 < R < 5000$ over a wavelength range of 0.6 - 27 µm.

3.7.1.13.7 Wavefront Sensing

MR-187 The ISIM shall contain a camera that provides the imagery required to support wavefront sensing.

3.7.1.13.8 Pupil Imaging

MR-380 Pupil Imaging shall be performed in the wavefront sensor.

3.7.1.13.9 Data Compression

MR-188 When commanded, the ISIM shall compress science data using at least a 2:1 lossless science data compression averaged over one day.

3.7.1.13.10 Data Compression Bypass

MR-189 The ISIM shall bypass data compression on command.

3.7.1.13.11 Event Driven Execution

MR-190 The ISIM shall manage the event–driven execution of the planned mission timeline.

3.7.1.13.12 Science Instrument Operations

MR-191 Excluding mechanical transients and the use of internal lamps, SI operations shall be independent of and not interfere with one another.

3.7.1.13.13 Fine Guidance Sensor Operations

MR-192 The FGS shall perform fine guidance independently and without interference to any SI operations.

3.7.1.13.14 Common Focus

MR-193 All science instruments and the guider shall meet their respective image quality and spectral resolution requirements after the OTE has been adjusted to an optimal focus position.

3.7.1.13.15 Restrictions on Optical Telescope Element Adjustment

MR-194 SIs shall not require OTE adjustment for any mode of instrument operation.

3.7.1.13.16 Science Instrument System Monitoring

MR-195 The ISIM shall continuously monitor SI subsystems for anomalies.

3.7.1.13.17 Integrated Science Instrument Module Safe Mode

MR-196 The ISIM shall place the instruments into a safe state without ground command upon detection or notification of anomalies. These anomalies may be either instrument, FGS, ISIM or Spacecraft anomalies.

3.7.1.13.18 ISIM Overhead

MR-394 After commissioning, the ISIM shall use no more than 3,652 hours over 5 years for overhead activities which detract from prime exposure time on scientific targets. This allocation includes time for ISIM safe mode down time, Guide Star identification, acquisition and retries, science instrument internal calibrations, and overheads associated with the set-up of science instrument for observations. The allocation is based on and will be verified by a hypothetical science program designed with 500, 90 degree slews and 8,000 small angle slews per year.

3.7.1.14 Optical Telescope Element

3.7.1.14.1 Primary Mirror Area

MR-198 The unobscured primary mirror area shall be greater than or equal to 25 square meters.

3.7.1.14.2 Optical Telescope Element Field of View

MR-199 The OTE shall not vignette the SI FOVs including all alignment tolerances.

Note: The FOVs are defined and controlled in the ISIM to OTE and Spacecraft Interface Requirements and Control Document, JWST-IRCD-000640 as IOS-IR-2302 and IOS-IR-4244.

3.7.1.14.3 Optical Area Transmission Product

MR-211 Accounting for all effects on mirror transmission including: coatings, particulate, molecular, water ice, photochemical decomposition, and meteoroid damage, the End of Life (EOL) area transmission product (i.e. unobscured area per MR-198 x transmission(λ) ≥ requirement(λ)) of the OTE shall be greater than the values shown in the following table for wavelengths between .8 micrometers and 2.0 micrometers, and greater than 22 m^2 for wavelengths from 2.0 micrometers to 27 micrometers, with transmission out to 29 micrometers as a goal.

Table 3-4. Optical Transmission

Wavelength (μm)	Area Transmission Product (m^2)
0.8	15.375
1.0	18.75
1.5	20.5
≥2.0	22.0

Note: 0.8 - 2 micrometer optical transmission is required for fine guidance and 1.0 - 2.0 micrometer optical transmission is required for wavefront sensing.

3.7.1.14.4 Vignetting

MR-226 The OTE optics, mounts, and baffles (except for secondary supports) shall not obstruct properly focused light from reaching the science focal planes.

3.7.1.14.5 Optical Telescope Element Wave Front Error Allocations

The OTE WFE allocation performance requirements define the maximum RMS WFE allowable for the OTE. These requirements apply to the optical system from the OTE primary mirror to the final focal plane of the OTE, and include allowances for thermal and mechanical error sources. The allocation includes line-of-sight stabilization and errors from vibration sources.

3.7.1.14.5.1 Optical Telescope Element Unvignetted Field of View Wavefront Error

MR-228 The OTE WFE shall be less than or equal to 131 nm RMS over the field of views of NIRCam, NIRSpec, and MIRI.

Note: The FOVs are defined and controlled in the ISIM to OTE and Spacecraft Interface Requirements and Control Document, JWST-IRCD-000640 as IOS-IR-2302 and IOS-IR-4244.

3.7.1.14.5.2 Optical Telescope Element Unvignetted Field of View Wavefront Error for FGS

MR-414 The OTE WFE shall be less than or equal to 150nm RMS over the field of view of the FGS.

Note: The FOVs are defined and controlled in the ISIM to OTE and Spacecraft Interface Requirements and Control Document, JWST-IRCD-000640 as IOS-IR-2302 and IOS-IR-4244.

3.7.1.15 Spacecraft

3.7.1.15.1 Communication Subsystem

3.7.1.15.1.1 Communication Operations

MR-232 The Observatory shall be designed to ensure that commanding is available on a continuous basis for 90% of 4-Pi steradian coverage as defined in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.15.1.2 Continuous Two-way Communication

MR-395 The Observatory shall be in continuous two-way communication with the Ground Segment from separation from the upper stage of the launch vehicle until the completion of Observatory Primary Mirror Phasing activities.

3.7.1.15.1.3 Launch Phase Communications

MR-407 The Observatory shall provide telemetry to the Ground Segment from launch vehicle payload fairing separation until separation from the upper stage of the launch vehicle.

3.7.1.15.1.4 Deep Space Network Compatibility

MR-408 The Observatory shall utilize the Deep Space Network to communicate with the Ground Segment.

3.7.1.15.1.5 Low Rate Commanding

MR-233 The Spacecraft shall be available to receive commands via the low data rate channels (250 bits per second [bps] and 2 kilobits per second [Kbps]) during initial deployment and in events requiring emergency communications.

3.7.1.15.1.6 Link Margins

MR-235 Radio frequency (RF) link margins for all links shall be at least +3dB in all operating and contingency modes, including a combination of root–sum–square (RSS) and worst–case adverse equipment tolerance variation.

3.7.1.15.1.7 Downlink of Uncompressed Recorded Engineering Data

MR-236 During a normal operations contact, the Observatory shall downlink the uncompressed recorded engineering data.

3.7.1.15.1.8 Stored Data Downlink

MR-237 The onboard data processing system shall utilize the Consultative Committee on Space Data Systems (CCSDS) File Data Protocol (CFDP) for downlink of stored science data and engineering telemetry.

3.7.1.15.1.9 Downlink of Compressed Science Data Volume

MR-409 During a normal operations contact, the Observatory shall be capable of downlinking to the Ground Segment 229 Gigabits of science data, which was compressed from 458 Gigabits.

3.7.1.15.1.10 Real-Time Data Downlink

MR-238 The onboard data processing system shall utilize the CCSDS protocol for real-time downlink of engineering telemetry.

3.7.1.15.1.11 Ranging

MR-239 The S-band link shall be used for ranging the Observatory.

3.7.1.15.1.12 Uplink

3.7.1.15.1.12.1 Command Uplink

MR-241 COP-1 and CFDP shall be utilized for command uplink as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.15.1.12.2 Command Uplink Frequency

MR-242 The command uplink shall be S–Band.

3.7.1.15.1.12.3 Low Rate Command Uplink

MR-243 The command uplink shall be at 250 bps.

3.7.1.15.1.12.4 Medium Rate Command Uplink

MR-244 The medium rate command uplink shall be 2 Kbps.

3.7.1.15.1.12.5 High Rate Command Uplink

MR-245 The high rate command uplink shall be 16 Kbps.

3.7.1.15.1.13 Downlink

3.7.1.15.1.13.1 Downlink Data Encoding

MR-248 The downlink shall be Reed-Solomon encoded.

3.7.1.15.1.13.2 Pseudo-Randomization of Data

MR-249 JWST data encoding on the Observatory shall include CCSDS randomization encoding for transmission to the ground.

3.7.1.15.1.13.3 Low Rate Downlink

MR-250 The low rate downlink shall be S-Band with characteristics as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.15.1.13.4 High Rate Downlink

MR-256 The high rate downlink shall be Ka-Band with characteristics as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.15.1.13.5 High Rate Downlink Data Rates

MR-257 The high rate downlink shall have selectable rates of 7, 14, 28 Megabits per second (Mbps) as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.1.15.1.14 Backup Communication Mode

3.7.1.15.1.14.1 Commanding

MR-259 The Spacecraft shall receive commands via S-Band at a minimum rate of 250 bps.

3.7.1.15.1.14.2 Telemetry

MR-260 The Spacecraft shall transmit telemetry via S-Band at a minimum rate of 200 bps during safe mode.

3.7.1.15.1.15 Real-Time Data Efficiency

MR-410 The Observatory shall transmit a minimum of 99.5% of all real-time telemetry to the Ground Segment.

3.7.1.15.1.16 Recorded Data Efficiency

MR-411 The Observatory shall transmit a minimum of 99.5% of all recorded data to the Ground Segment.

3.7.1.15.2 Electrical Power Subsystem

MR-261 The Electrical Power Subsystem (EPS) shall provide conditioned power to the Observatory during all mission phases.

3.7.1.15.2.1 Voltage

MR-262 The EPS shall distribute direct current power to the loads at 28 V +7/-6 at the interface connectors.

3.7.1.15.2.2 Circuit Protection

MR-264 Circuit protection devices shall be sized to protect primary power cable wiring harnesses.

3.7.1.15.2.3 Power Return

MR-265 All primary power returns shall be via hardwires to the EPS single prime power ground point.

3.7.1.15.3 Structural and Mechanical

3.7.1.15.3.1 Mechanisms

MR-268 In order to assure their capability and reliability to support all JWST mission requirements, Observatory mechanisms shall have functional redundancy such that no single failure prevents the Observatory from meeting mission requirements or be designed, manufactured, integrated and tested to the requirements of the JWST Mechanisms Control Requirements (JWST-RQMT-004058).

3.7.1.15.4 Observatory Thermal Subsystem

MR-269 The thermal control system shall regulate the temperatures and rates of temperature changes of the JWST Observatory within safe and operational limits as appropriate for all mission phases and during all thermal environmental extremes that the Observatory may encounter.

3.7.1.15.4.1 Architecture

MR-270 The Observatory architecture shall allow for the passive cooling of ISIM-related components and electronics to their safe and operational limits.

3.7.1.15.4.2 Near-Infrared Detector Cooling

MR-271 The Observatory shall passively cool the Near-Infrared (NIR) Science Detectors to a temperature of less than or equal to 37K beginning at a time during commissioning that supports NIRCam and NIRSpec commissioning and continuing until the end of the science mission lifetime.

3.7.1.15.5 Propellant Lifetime

MR-48 Propellant shall be sized for 10 years of operation after launch.

3.7.1.15.6 Health and Safety Responsibility

MR-272 The Spacecraft shall be responsible for the health and safety of the Observatory.

3.7.1.15.7 Fault Tolerance

MR-273 The Observatory shall be autonomously single fault tolerant against all credible failures that may result in loss of the mission.

3.7.1.15.8 Fault Propagation

MR-274 The design of the Observatory shall preclude propagation of the effects of part failures beyond the component containing the part that fails.

3.7.1.15.9 Cross Strapping

MR-275 Redundant Observatory functionality shall be cross-strapped. This does not include primary power.

3.7.1.15.10 Safe Modes

MR-276 The Observatory shall enter safe modes and reconfigure its onboard systems in response to anomalies when configured for safe mode entry.

3.7.1.15.10.1 Safe Mode Hierarchy

MR-277 Consistent with the nature and severity of the anomaly, the Observatory's safe modes shall have a least-to-greatest hierarchical impact on the mission timeline.

3.7.1.15.10.2 Safe Mode Consumables

MR-278 All safe modes shall be designed to conserve consumables.

3.7.1.15.10.3 Autonomous Safe Mode Duration

MR-279 The Observatory shall sustain an autonomous safe mode for 4 weeks without Ground Segment intervention.

3.7.1.15.10.4 Safe Mode Commanding

MR-280 The Observatory shall exit safe modes via Ground Segment commands.

3.7.1.15.10.5 Safe Haven Mode Data Handling

MR-281 While in Safe Haven mode the Observatory shall retain recorded data while simultaneously down-linking the recorded data and real–time engineering data to support anomaly investigation and recovery to normal operations.

3.7.1.16 Launch Vehicle Interface

MR-282 The JWST Observatory shall meet the interface requirements to the Launch Segment defined in the Application to Use Ariane (DUA) IRD (JWST-IRD-003674).

3.7.2 <u>Launch Segment</u>

3.7.2.1 Launch Vehicle

MR-283 The JWST Observatory launch vehicle shall be an Arianespace Ariane 5 Evolved Cryogenic Upper Stage Type-A (ECA) with a 5-meter diameter, long (single) payload fairing.

3.7.3 <u>Ground Segment</u>

3.7.3.1 Orbit

3.7.3.1.1 Orbit Maximum Z Excursion

MR-396 The Ground Segment shall calculate the delta velocity needed to maintain the Observatory in orbit about L2 in the Z direction (defined in Figure 3-2) to less than or equal to 500,000 Km.

3.7.3.1.2 Orbit Maximum Y Excursion

MR-397 The Ground Segment shall calculate the delta velocity needed to maintain the Observatory in orbit about L2 in the Y direction (defined in Figure 3-2) to less than or equal to 800,000 Km.

3.7.3.1.3 Eclipse Prevention

MR-398 The Ground Segment shall maintain the orbit about L2 such that the Observatory does not enter an Earth or Moon eclipse.

3.7.3.2 Wavefront Sensing and Control Executive

MR-285 The S&OC shall house the Executive that executes wavefront sensing and control (WFS&C) algorithms and generates WFS&C command content.

3.7.3.3 Observatory Wavefront Maintenance

MR-286 The Ground Segment shall generate wavefront error correction commands for uplink to the Observatory from the downlinked wavefront sensing data.

3.7.3.4 Ground Segment Overhead

MR-287 After commissioning, the Ground Segment shall contribute observation idle time overhead of no more than 2,192 hours over a 5-year period due to the following overhead activities: Observation Plan Scheduling, Target of Opportunity Scheduling, Anomaly Recovery for all Safemode Events, Ground Segment-caused Safemode Events, Ground Segment Outages interfering with observations, and Engineering Tests. The allocation is based on and will be verified by a hypothetical science program designed with 500, 90 degree slews and 8,000 small angle slews per year.

3.7.3.5 Observatory Operations

MR-288 The Ground Segment shall be used to maintain and operate the JWST Observatory from launch to the end of the mission.

3.7.3.5.1 Continuous Communication

MR-399 The Ground Segment shall be in continuous communication with the Observatory from separation from the upper stage of the launch vehicle until the completion of Observatory Primary Mirror Phasing activities.

3.7.3.5.2 Normal Operations

MR-289 One year after the launch of the JWST Observatory, and in the absence of anomalies, the S&OC shall continuously operate the Observatory safely with 8 hours per day, 5 days per week staffing.

3.7.3.5.2.1 Unattended Operations

MR-290 The Ground Segment shall have an unattended operational mode that monitors flight system telemetry and Ground Segment status autonomously, and automatically alerts on–duty and/or remote, off–duty personnel of system problems requiring human intervention.

3.7.3.5.3 Mission Operations

MR-291 The S&OC shall plan and conduct JWST science and mission operations, and interact real-time with the Observatory for both routine and contingency activities.

3.7.3.5.3.1 Execution of Mission Timeline

MR-292 The Ground Segment shall generate and uplink for execution by the Observatory, an event driven schedule.

3.7.3.5.3.2 Timeline Recovery and Modification

MR-293 The S&OC shall be able to recover or modify the mission timeline within 24 hours of the decision to proceed.

3.7.3.6 Science Instrument FOV Pointing Knowledge

MR-400 The Ground Segment shall determine the a posteriori pointing knowledge for the SI FOVs to within 1 arsec (1-sigma, radial) of their true positions in the celestial coordinate frame. For imaging and spectroscopic data, this applies over the entire SI FOV.

3.7.3.7 Transfer Orbit and Operational Orbit Determination

MR-294 The Ground Segment shall perform transfer orbit and operational orbit determination.

3.7.3.8 Software Maintenance

3.7.3.8.1 Ground Master Image

MR-296 The Ground Segment shall store and maintain a ground master image of onboard computer software, tables and data loads.

3.7.3.8.2 Software Configuration Archive

MR-297 The S&OC shall maintain an archive of all ground master images and associated documentation.

3.7.3.8.3 Software Update

MR-298 The Ground Segment shall store, archive and update onboard computer software, tables and data loads.

3.7.3.8.4 Mean Time to Repair

MR-165 The flight software repair process which includes the process starting with code compilation and ending with the delivery of the uploadable package to operations (not including verification) shall take less than 24 hours for the entire flight software system on a single processor.

3.7.3.9 Project Reference Data Base

MR-299 The S&OC shall contain the Project Reference Data Base of all JWST descriptors, commands, parameters, algorithms, characteristics, and other data and information required to operate the Observatory.

3.7.3.9.1 Observatory Information Source

MR-300 The Project Reference Data Base shall be the exclusive source for information used to operate the Observatory.

3.7.3.9.2 Integration and Test

MR-301 The Project Reference Database shall be used as the baseline database, to provide an initial source of configured data and to provide a basis for tracking changes, for subsystems and higher level integration and test.

3.7.3.9.3 Validation Prior to Use

MR-302 Data stored in the Project Reference Data Base shall be validated prior to release to operations.

3.7.3.10 Data Archiving

3.7.3.10.1 Archive Catalog

MR-307 The Ground Segment shall maintain an on-line archive catalog that is accessible to current and prospective users of JWST data.

3.7.3.10.2 Other Contents

MR-308 The archive shall also contain the historical and current calibration parameters, coefficients, and algorithms needed to transform raw engineering and science telemetry into calibrated measurements expressed in standard units.

3.7.3.10.3 Multiple Copies

MR-309 The data archive shall produce and retain a second, safe copy of all JWST data sets received.

3.7.3.10.4 Provision of Data to International Partners

MR-310 The Ground Segment shall distribute data to other archive facilities as provided by the terms of agreements negotiated between NASA and its international partners.

3.7.3.10.5 Temporary Storage of Real-Time Telemetry

MR-311 Observatory real–time data forwarded to the S&OC shall be retained until the copy of the data recorded on-board has been received and verified.

3.7.3.10.6 Processing Efficiency

MR-312 Down linked data will be archived within 24 hours of receipt 90% of the time.

3.7.3.10.7 Output Products

MR-313 Raw data, calibrated data and/or calibration parameters shall be supplied upon request.

3.7.3.10.7.1 Product Format

MR-314 Requested archive data shall be supplied electronically.

3.7.3.10.7.2 Use of Up-to-Date Calibrations

MR-315 Calibrated data (i.e., data processed to remove instrument signatures) shall be supplied upon request, using the most current calibrations applicable to the data set.

3.7.3.10.8 Availability of New Data

MR-316 The data archive shall make new science data sets available electronically to the Principal Investigator (PI) of the observing program.

3.7.3.10.8.1 Timeliness of Delivery

MR-317 Science data shall be available at the ground segment data archive within 5 days of receipt at the S&OC.

3.7.3.10.9 Archival Research

MR-318 Electronic availability of JWST science data sets to archival researchers shall commence as soon as the PI proprietary data period expires.

3.7.3.11 Health and Safety

3.7.3.11.1 Health and Safety Protections

MR-320 S&OC health and safety protections shall preclude the violation of hardware and software constraints.

3.7.3.11.2 Deliberate Override

MR-321 S&OC health and safety protections shall require deliberate overrides to hardware and software restrictions that normally prevent non–standard commanding to or configurations of Observatory components.

3.7.3.12 Real-Time Systems and Functions

MR-322 The common commanding and telemetry processing system, or copies of it, shall be used from subsystem integration and test through operations.

3.7.3.12.1 Availability

MR-323 The S&OC real-time system shall be available a minimum of 99% of the time during communications contacts averaged over one year.

3.7.3.12.2 Capability for Real-Time Commanding

MR-324 The real-time system shall have the capability to send commands intended for priority execution by the Observatory in conjunction with the on–going execution of stored commands.

3.7.3.12.3 Prevention of Mutual Interference

MR-325 Protections shall exist to prevent the mutual interference of real–time and stored commanding.

3.7.3.12.4 Primary and Backup Systems

MR-326 The S&OC shall maintain independent primary and back–up real–time systems.

3.7.3.12.5 Mission Critical Operations

MR-327 Mission–critical operations shall have back–up systems configured as “hot” backups with a fail–over time of 10 minutes or less.

3.7.3.12.6 Transfer of Non-Critical Operations

MR-328 Transfer of non-critical, real-time operations from primary to backup, or vice versa, shall require one hour or less.

3.7.3.12.7 Test Support

MR-329 Testing that is independent of real-time operation shall use the backup real-time system.

3.7.3.12.8 Science and Operations Center Alternate Facility

MR-330 The Ground Segment shall implement the transfer of health and safety operations to an alternate facility within 90 minutes of a catastrophic failure at the primary S&OC site.

3.7.3.12.9 Command Function Security

MR-331 The S&OC shall be the sole and secure originator of commands sent to the Observatory, as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.3.12.9.1 Command Authentication

MR-415 During normal operations, the Ground Segment shall uplink commands that meet the authentication protocol specified in the JWST Flight Observatory to Ground Segment Interface Requirements and Control Document (JWST-IRCD-000696).

3.7.3.12.10 Command Uplink

MR-334 The Ground Segment shall uplink commands to the Observatory.

3.7.3.12.11 Command Verification

MR-335 The Ground Segment shall verify command receipt by the Observatory.

3.7.3.12.12 Observatory Monitoring

MR-336 The Ground Segment shall monitor JWST Observatory status for compliance with planned operations and for conditions that indicate JWST health and safety.

3.7.3.12.13 Real-Time Telemetry Monitoring

MR-337 The real-time data system shall be able to monitor Observatory health, safety and operational status.

3.7.3.12.14 Real-Time Engineering Data Forwarding

MR-338 Real-time JWST engineering data received at a ground station supporting the mission shall be forwarded to the S&OC within 1 minute.

3.7.3.12.15 Stored Engineering Data Forwarding Start

MR-339 The DSN shall begin forwarding stored engineering data to the S&OC within 15 minutes of receipt.

3.7.3.12.16 Data Forwarding Data Rate

MR-401 The DSN shall forward data to the S&OC at a minimum data rate of 10 Gigabits per 30 minutes.

3.7.3.12.17 Stored Science Data Forwarding

MR-376 JWST stored science data shall be forwarded to the S&OC within 8 hours of receipt by the DSN.

3.7.3.12.18 Receipt of Uncompressed Recorded Engineering Data

MR-377 During a normal operations contact, the Ground Segment shall receive the uncompressed recorded engineering data.

3.7.3.12.19 Receipt of Compressed Science Data Volume

MR-412 During normal operations contact the Ground Segment shall be capable of receiving 229 Gigabits of science data, which was compressed from 458 Gigabits.

3.7.3.12.20 Emergencies

3.7.3.12.21 Ground Real Time Data Transfer

MR-402 The Ground Segment shall transfer to the S&OC 94% of real time data that reaches the Ground Segment.

3.7.3.12.22 Ground Recorded Data Transmittal

MR-403 The Ground Segment shall archive 98% of recorded data that reaches the Ground Segment.

3.7.3.13 Off-Line Systems and Functions

MR-343 The Ground Segment shall create valid event driven observing plan files containing all the data needed to execute flight segment activities via stored commanding.

3.7.3.13.1 Science Proposal Support

MR-344 The Ground Segments S&OC shall receive process and peer review JWST science proposals.

3.7.3.13.2 Observation Modifications

MR-345 The Ground Segment shall permit observers to modify observation content between proposal submission and the uplink of observing plan files, subject to policies governing time allocations, target specifications and program objectives.

3.7.3.13.3 Performance Trending

MR-347 The Ground Segment shall perform trending analysis of Observatory performance.

3.7.3.13.4 Calibration Trending Analysis

MR-348 The Ground Segment shall perform trending analysis of Observatory subsystem and telemetry data calibrations.

3.7.3.13.5 Observatory Subsystem Calibration

MR-349 The Ground Segment shall calibrate the performance of Observatory subsystems.

3.7.3.13.6 Observatory Telemetry Calibration

MR-350 The Ground Segment shall calibrate Observatory telemetry data.

3.7.3.13.7 Simulators and Models

MR-351 The Ground Segment shall include Observatory subsystems hardware, software and operations simulators, and models for anomaly resolution, hardware re–configuration, software checkout and personnel training.

3.7.3.14 Ground Segment Communication Support For Normal Operations

MR-352 The Ground Segment shall provide a minimum of 4 hours of contact time per day with the Observatory.

3.7.3.14.1 Deep Space Network Antenna

MR-353 The DSN antenna diameter shall be 34 meters as specified in the JWST Flight Observatory to Ground Segment IRCD (JWST-IRCD-000696).

3.7.3.14.2 S-Band Emergency Services

MR-354 The Ground Segment shall be able to obtain extended forward and return S-band service in the event of an Observatory emergency.

3.7.3.14.2.1 Response Time

MR-355 The response time for obtaining S–band emergency services shall be 2 hours or less.

3.7.3.14.2.2 Continuity of Service

MR-356 Acquired communications coverage shall be 24 hours per day, seven days per week for the duration of the emergency.

3.7.3.14.3 Ka-Band Emergency Service

MR-357 The Ground Segment shall be able to obtain extended return Ka-Band service in the event of an Observatory emergency.

3.7.3.14.4 Ground Segment Support for Continuous Two-way Communication (S-Band)

MR-378 From separation from the upper stage of the launch vehicle until the completion of Primary Mirror Phasing activities, the Ground Segment shall be in continuous two-way S-band link communications.

3.7.3.14.5 Launch Phase Communications

MR-413 The Ground Segment shall receive telemetry from the Observatory via the S-band link from launch vehicle payload fairing separation until separation from the upper stage of the launch vehicle.

3.7.3.14.6 Ground Segment Support for Continuous Communication (Ka-Band)

MR-234 From High Gain Antenna deployment to completion of Primary Mirror Phasing activities, the Ground Segment shall have a continuous Ka-Band return link with the Observatory.

4.0 QUALIFICATION ASSURANCE PROVISIONS

4.1 GENERAL

All requirements in this document shall be verified by one of the four methods defined below.

4.1.1 Analysis

The analysis method is used when:

- a rigorous, representative, and conclusive analysis is possible
- test is not cost effective, and
- inspection and demonstrations are not adequate.

Analyses may include, but are not limited to, engineering analysis (which includes models and simulations), review of records, and similarity analysis.

4.1.1.1 Engineering Analysis

Engineering analysis may be quantitative, qualitative or a combination of the two. Quantitative analysis involves the study and modeling of the physical entity whose performance is to be verified. Examples of quantitative analyses include end-to-end link analysis, structural (static and dynamic) analysis, thermal models, pointing knowledge and stability. Qualitative analyses are non-numerical and relate to qualitative measure of performance, such as failure modes and effects analyses (FMEA), maintainability, and redundancy.

4.1.1.2 Analysis of Records and Other Documentation

This kind of analysis uses design and manufacturing documentation to show compliance of design features and manufacturing processes. Analysis of design documentation verifies that the "as-designed" hardware and/or software complies with contractual design and construction requirements. Analysis of manufacturing records at end-item acceptance verifies that the "as-built" hardware or software has been fabricated per the approved design and associated documentation. Review and analysis of other documentation such as acceptance data packages and other compliance documentation of lower levels of assembly are valid analysis techniques.

4.1.1.3 Similarity Analysis

Similarity is included as a valid verification/qualification method. Qualification by similarity is used in lieu of test when it can be shown that an item is similar to, or identical in design to another item that has been previously qualified to equivalent, or more stringent requirements. Formal qualification documentation of the previously qualified item must be available for assessment when planning to qualify by similarity. Furthermore, an item whose design has been qualified by similarity must undergo acceptance verification to assess workmanship.

4.1.2 Demonstration

Demonstration is a verification method that provides a qualitative determination, rather than direct quantitative measurement, of the properties or functional characteristics of an end-item. The qualitative determination is made through observation with, or without test equipment or instrumentation. The demonstration method is primarily used to show compliance with human engineering requirements, transportability, as well as service and access requirements. Demonstration may be used for ground segment software as a final step in verification of high-level system requirements, where a complete characterization of the end state of the system is not feasible.

4.1.3 Inspection

Inspection is the verification method used to verify construction features, workmanship, dimension, physical characteristics, and spacecraft conditions such as configuration, cleanliness, and locking hardware. Inspection also includes simple measurements such as length, and it is performed without the use of special laboratory or precision equipment. In general, requirements specifying function or performance are not verified by inspection.

4.1.4 Test

Verification by test consists of direct measurement of performance parameters relative to functional, electrical, mechanical, and environmental requirements. These measurements are obtained, during or after controlled application of functional and environmental stimuli to the test article, e.g., payload or satellite, and using instrumentation or special test equipment that is not an integral part of the test article being verified. The test activities include reduction and analysis of the test data, as appropriate. The following paragraphs define different categories of tests including performance, functional, environmental, interface, and structural tests.

4.1.4.1 Performance Test

A performance test consists of an individual test or series of electrical and/or mechanical tests conducted on flight, or flight-configured hardware and software at conditions equal to, or less than design specifications. Its purpose is to verify compliance of the test article with the stated applicable specification requirements that are verifiable by test. Typically, a full performance test is conducted at ambient conditions at the beginning and end of a test sequence during which the test article is subjected to applicable environmental conditions, e.g., vacuum, high/low temperature extremes, or acoustics/random mechanical excitation.

4.1.4.2 Functional Tests

A functional test is a suitably chosen subset of a performance test. Typically, functional tests are conducted at ambient conditions between environmental exposures during the qualification or acceptance test sequence. The objective is to verify that prior to application of the next environment, exposure to the environment has not adversely affected the test article. When appropriate, functional tests, or a portion thereof, are conducted while the test article is exposed to a particular thermal or vacuum environment. Functional test, or a portion thereof, may also be conducted to assess the state of health of the hardware after major operations, such as transportation of flight hardware from one location to another.

4.1.4.3 Environmental Tests

Environmental testing is an individual test or series of tests conducted on flight, or flight-configured hardware, to assure that flight hardware will perform satisfactorily after it is subjected to the induced launch environments, as well as its flight environment. Examples are: vibration, acoustic, temperature cycling, thermal vacuum and vacuum out-gassing certification, and Electromagnetic Interference/Compatibility. Depending on the severity of the chosen environmental conditions, the purpose of the environmental exposure is to sufficiently stress the hardware so as to verify the adequacy of the design (protoflight levels and durations) or workmanship during fabrication (acceptance levels and durations).

4.1.4.4 Special Tests

Special tests are individual tests, or a series of tests conducted on flight, or flight-configured hardware to assure satisfactory performance of a particular critical element of the system, e.g., optical alignment. The special test verification category includes structural, mechanism and communication tests. Special tests may, or may not be performed in conjunction with environmental exposure.

4.1.4.5 Interface Tests

Interface tests verify the mechanical, electrical, and/or hardware-software interface between units and elements integrated into a higher level of assembly such as a module, subsystem, element or a system.

4.1.4.6 Structural Tests

These tests are performed on structural elements, components, or assembled subsystems before delivery of the assembled structure to the integration and test organization. Structural tests designed to verify requirements of this specification may include: (1) static structural proof tests (to verify the strength/stiffness adequacy of the primary load path), and (2) dynamic tests, such as a modal survey or acoustic response test.

4.1.4.7 Software Tests

Software testing is performed to verify and validate flight and ground software.

4.2 VERIFICATION TABLE

The following matrix defines the method of verification for all requirements contained in this document.

Table 4-1. Verification Table

Verification Method:
Inspection (I)
Analysis (A)
Demonstration (D)
Test (T)

Level:
II System
III Segment
IV Element
V Subsystem

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-92	3.1.4	Units	I				MSE
MR-40	3.2.1.1.1	Transfer Orbit		A			MSE
MR-41	3.2.1.1.2	Operational Orbit		A			MSE
MR-385	3.2.1.1.2.1	Orbit Maximum Z Excursion		A			MSE
MR-386	3.2.1.1.2.2	Orbit Maximum Y Excursion		A			MSE
MR-387	3.2.1.1.2.3	Eclipse Prevention		A			MSE
MR-42	3.2.1.1.3	Operational Orbit Transfer		A			MSE
MR-44	3.2.1.2.1	Science Mission Lifetime		A			MSE
MR-45	3.2.1.2.2	Commissioning Phase Duration		A			Observatory
MR-49	3.2.1.3	Real-time Data Efficiency		A			MSE
MR-50	3.2.1.4	Recorded Data Efficiency		A			MSE
MR-51	3.2.1.5	Sensitivity		A		T	MSE
MR-125	3.2.1.6	Contamination Control		A			Observatory
MR-379	3.2.1.7	Pupil Imaging		A			MSE
MR-76	3.2.1.8	Downlink of Compressed Science Data Volume			D		MSE
MR-77	3.2.1.9	Normal Operations		A			MSE
MR-78	3.2.1.10	Continuous Two-way Communication		A			MSE
MR-405	3.2.1.11	Launch Phase Communications		A			MSE
MR-79	3.2.1.12	Command Bit Error Rate		A			Observatory
MR-80	3.2.1.13	Telemetry Bit Error Rate		A			Observatory
MR-381	3.2.1.14	Nominal Data Quality		A			Observatory
MR-384	3.2.1.15	Image-Based Wavefront Sensing and Control		A			MSE
MR-102	3.2.1.16	JWST System Efficiency		A			MSE
MR-120	3.2.1.17	Field Distortion Uncertainty		A			MSE
MR-82	3.2.2.1	Deep Space Network				T	MSE
MR-84	3.2.3.1	Single Failure		A			MSE
MR-90	3.3.1	Thermal Design Margins		A			MSE
MR-91	3.3.2	Calculated Heat Rejection Capacity Margins for Cryogenic Systems		A			

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-406	3.7.1.1.1	Orbit Range		A			Observatory
MR-388	3.7.1.1.2	Maximum Z Excursion		A			Observatory
MR-389	3.7.1.1.3	Orbit Maximum Y Excursion		A			Observatory
MR-99	3.7.1.2.1	Observatory Mass Allocation	I				Observatory
MR-100	3.7.1.2.2	Mission Unique Launch Vehicle Accommodation		A			Observatory
MR-390	3.7.1.3	Observatory Overhead		A			Observatory
MR-103	3.7.1.4.1	Annual Coverage		A			Observatory
MR-104	3.7.1.4.2	Field of Regard		A			Observatory
MR-105	3.7.1.4.3	Consecutive Coverage		A			Observatory
MR-106	3.7.1.4.4	Continuous Visibility Zone		A			Observatory
MR-107	3.7.1.5	Wavelength Range		A		T	Observatory
MR-368	3.7.1.6.1	Spacecraft and Optical Telescope Element Reliability		A			Observatory
MR-383	3.7.1.6.2	ISIM Reliability		A			Observatory
MR-110	3.7.1.7.1.1	Strehl Ratio		A			Observatory
MR-113	3.7.1.7.1.2.1	24 Hour Encircled Energy Stability		A			Observatory
MR-114	3.7.1.7.1.2.1.1	Conditions		A			Observatory
MR-115	3.7.1.7.1.2.2	Encircled Energy Long Term Stability		A			Observatory
MR-116	3.7.1.7.2	Strehl Ratio for Mid-Infrared Instrument		A			Observatory
MR-121	3.7.1.7.3	Stray Light at Near-Infrared Wavelengths		A			Observatory
MR-122	3.7.1.7.4	Stray Light From Thermal Emissions		A			Observatory
MR-371	3.7.1.7.5.1	Strehl Ratio For Moving Targets		A			Observatory
MR-123	3.7.1.8	Image Based Wavefront Sensing		A		T	Observatory
MR-124	3.7.1.9	Wavefront Error Correction Capability			D		Observatory
MR-391	3.7.1.10	Normal Operations		A			Observatory
MR-127	3.7.1.11.1	Observatory Event Logs				T	Observatory
MR-128	3.7.1.11.2	Command Authentication				T	Observatory
MR-129	3.7.1.11.3	On-Board Storage				T	Observatory
MR-130	3.7.1.11.3.1	Storage Capacity			D		Observatory
MR-133	3.7.1.11.3.2.1	Science Exposure Identification		A		T	Observatory
MR-134	3.7.1.11.3.2.2	Science Observation Identification		A		T	Observatory
MR-135	3.7.1.11.3.3	Simultaneous Onboard Storage				T	
MR-137	3.7.1.11.4	Common Data Bus, Point to Point, and Power Interfaces	I				Observatory
MR-138	3.7.1.11.5	Processor Utilization		A			Observatory
MR-139	3.7.1.11.6	Local and External Data Bus Utilization		A		T	Observatory
MR-142	3.7.1.11.7.1	Coordinated Universal Time Correlation Accuracy				T	Observatory
MR-143	3.7.1.11.7.2	Coordinated Universal Time Clock		A			Observatory

Requirement Number		Object Heading	I	A	D	T	Responsible Org
		Maintenance					
MR-145	3.7.1.11.8.1	Capability for Real-Time Commanding				T	Observatory
MR-146	3.7.1.11.8.2	Prevention of Mutual Interference				T	Observatory
MR-147	3.7.1.11.8.3	Command Safety		A		T	Observatory
MR-148	3.7.1.11.8.4	Command Verification				T	Observatory
MR-149	3.7.1.11.8.5	Report Verified Commands				T	Observatory
MR-150	3.7.1.11.8.6	Command Validation				T	Observatory
MR-151	3.7.1.11.8.7	Report Validated Commands				T	Observatory
MR-152	3.7.1.11.8.8	Report Executed Commands				T	Observatory
MR-153	3.7.1.11.8.9	Command Rejection				T	Observatory
MR-156	3.7.1.11.9.1	Parallel Operations		A		T	Observatory
MR-157	3.7.1.11.9.2	Autonomous Operation		A			Observatory
MR-158	3.7.1.11.9.3	Observatory Replan Accommodation				T	Qbservatory
MR-159	3.7.1.11.10.1	Data Playback				T	Observatory
MR-375	3.7.1.11.10.2	Interleave Real-time with Recorded Data			D		Observatory
MR-161	3.7.1.11.11.1	Event-Driven Observatory Operations		A			Observatory
MR-162	3.7.1.11.11.2	Common Command and Data Handling Operating System		A			Observatory
MR-163	3.7.1.11.11.3	Flight Software Common Programming Language		A			Observatory
MR-166	3.7.1.11.11.4.1	In-Flight Updates		A		T	Observatory
MR-392	3.7.1.11.11.4.2	Volatile Memory Reloading				T	Observatory
MR-366	3.7.1.11.12	Memory Margin		A			Observatory
MR-382	3.7.1.11.13	Nominal Observatory Data Loss		A			Observatory
MR-168	3.7.1.12.1	Sun Damage		A			Observatory
MR-170	3.7.1.12.2.1	Guiding Capability		A			Observatory
MR-171	3.7.1.12.2.2	Guide Star Availability		A			Observatory
MR-365	3.7.1.12.2.3	Single Point Failure		A		T	Observatory
MR-372	3.7.1.12.3	Moving Target Tracking		A		T	Observatory
MR-172	3.7.1.12.4	Observatory Optical Telescope Element Boresight Coarse Pointing Accuracy		A			Observatory
MR-173	3.7.1.12.5	Fine Guidance Pointing Accuracy		A			Observatory
MR-174	3.7.1.12.6	Relative Offset Pointing Repeatability		A			Observatory
MR-175	3.7.1.12.7	Science Instrument FOV Pointing Knowledge Data		A			Observatory
MR-393	3.7.1.12.8	Absolute Pointing Knowledge		A			MSE
MR-176	3.7.1.12.9	Field Orientation Knowledge		A			Observatory
MR-177	3.7.1.12.10	Field of View Orientation		A			Observatory
MR-178	3.7.1.12.11	Re-pointing		A			Observatory
MR-179	3.7.1.12.12	Small Maneuver Slew Rate		A			Observatory

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-180	3.7.1.12.13	Medium Maneuver Slew Rate		A			Observatory
MR-182	3.7.1.12.14	Field of View Offsets, 0.0 - 0.5 Arc-second		A			Observatory
MR-181	3.7.1.12.15	Field of View Offsets, 0.5 - 2.0 Arc-second		A			Observatory
MR-374	3.7.1.12.16	Field of View Offsets, 2.0 - 20 Arcsec		A			Observatory
MR-364	3.7.1.12.17	Field of View Offsets, 20 - 45 Arcsec		A			Observatory
MR-184	3.7.1.13.1	Integrated Science Instrument Module Mass	I				Observatory
MR-373	3.7.1.13.2	Integrated Science Instrument Module Power Allocation		A			Observatory
MR-369	3.7.1.13.3	Science Instruments and Guiders Allocated Field of View		A		T	Observatory
MR-370	3.7.1.13.4	Science Instruments and Guiders Field of View		A			Observatory
MR-185	3.7.1.13.5	Imagery Spectral Bandwidths		A		T	Observatory
MR-186	3.7.1.13.6	Spectroscopy Spectral Resolution		A		T	Observatory
MR-187	3.7.1.13.7	Wavefront Sensing	I				Observatory
MR-380	3.7.1.13.8	Pupil Imaging		A			Observatory
MR-188	3.7.1.13.9	Data Compression		A			Observatory
MR-189	3.7.1.13.10	Data Compression Bypass				T	Observatory
MR-190	3.7.1.13.11	Event Driven Execution		A			Observatory
MR-191	3.7.1.13.12	Science Instrument Operations				T	ISIM
MR-192	3.7.1.13.13	Fine Guidance Sensor Operations				T	ISIM
MR-193	3.7.1.13.14	Common Focus		A		T	Observatory
MR-194	3.7.1.13.15	Restrictions on Optical Telescope Element Adjustment		A			ISIM
MR-195	3.7.1.13.16	Science Instrument System Monitoring				T	ISIM
MR-196	3.7.1.13.17	Integrated Science Instrument Module Safe Mode				T	ISIM
MR-394	3.7.1.13.18	ISIM Overhead		A			ISIM
MR-198	3.7.1.14.1	Primary Mirror Area	I				OTE
MR-199	3.7.1.14.2	Optical Telescope Element Field of View		A			OTE
MR-211	3.7.1.14.3	Optical Transmission		A		T	OTE
MR-226	3.7.1.14.4	Vignetting		A			Observatory
MR-228	3.7.1.14.5.1	Optical Telescope Element Unvignetted Field of View Wavefront Error		A			Observatory
MR-232	3.7.1.15.1.1	Communication Operations		A			Observatory
MR-395	3.7.1.15.1.2	Continuous Two-Way Communication		A			Observatory
MR-407	3.7.1.15.1.3	Launch Phase Communications		A			Observatory
MR-408	3.7.1.15.1.4	Deep Space Network Capatibility		A			Observatory
MR-233	3.7.1.15.1.5	Low Rate Commanding		A		T	Spacecraft

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-235	3.7.1.15.1.6	Link Margins		A			Observatory
MR-236	3.7.1.15.1.7	Downlink of Uncompressed Recorded Engineering Data		A			Observatory
MR-237	3.7.1.15.1.8	Stored Data Downlink			D		Observatory
MR-409	3.7.1.15.1.9	Downlink of Compressed Science Data Volume		A			Observatory
MR-238	3.7.1.15.1.10	Real-Time Data Downlink			D		Observatory
MR-239	3.7.1.15.1.11	Ranging		A			Observatory
MR-241	3.7.1.15.1.12.1	Command Uplink			D		Observatory
MR-242	3.7.1.15.1.12.2	Command Uplink Frequency			D		Observatory
MR-243	3.7.1.15.1.12.3	Low Rate Command Uplink		A		T	Observatory
MR-244	3.7.1.15.1.12.4	Medium Rate Command Uplink		A		T	Observatory
MR-245	3.7.1.15.1.12.5	High Rate Command Uplink		A		T	Observatory
MR-248	3.7.1.15.1.13.1	Downlink Data Encoding			D		Observatory
MR-249	3.7.1.15.1.13.2	Pseudo-Randomization of Data			D		Observatory
MR-250	3.7.1.15.1.13.3	Low Rate Downlink		A		T	Observatory
MR-256	3.7.1.15.1.13.4	High Rate Downlink		A		T	Observatory
MR-257	3.7.1.15.1.13.5	High Rate Downlink Data Rates		A		T	Observatory
MR-259	3.7.1.15.1.14.1	Commanding				T	Observatory
MR-260	3.7.1.15.1.14.2	Telemetry				T	Observatory
MR-410	3.7.1.15.1.15	Real-Time Data Efficiency		A			Observatory
MR-411	3.7.1.15.1.16	Recorded Data Efficiency		A			Observatory
MR-261	3.7.1.15.2	Electrical Power Subsystem		A			Observatory
MR-262	3.7.1.15.2.1	Voltage		A			Observatory
MR-264	3.7.1.15.2.2	Circuit Protection		A			Observatory
MR-265	3.7.1.15.2.3	Power Return	I				Observatory
MR-268	3.7.1.15.3.1	Mechanisms		A			Observatory
MR-269	3.7.1.15.4	Observatory Thermal Subsystem		A			Observatory
MR-270	3.7.1.15.4.1	Architecture		A			Observatory
MR-271	3.7.1.15.4.2	Near-Infrared Detector Cooling		A			Observatory
MR-48	3.7.1.15.5	Propellant Lifetime		A			Observatory
MR-272	3.7.1.15.6	Health and Safety Responsibility		A			Observatory
MR-273	3.7.1.15.7	Fault Tolerance		A			Observatory
MR-274	3.7.1.15.8	Fault Propagation		A			Observatory
MR-275	3.7.1.15.9	Cross Strapping		A			Observatory
MR-276	3.7.1.15.10	Safe Modes		A		T	Observatory
MR-277	3.7.1.15.10.1	Safe Mode Hierarchy				T	Observatory
MR-278	3.7.1.15.10.2	Safe Mode Consumables		A			Observatory
MR-279	3.7.1.15.10.3	Autonomous Safe Mode Duration		A			Observatory
MR-280	3.7.1.15.10.4	Safe Mode Commanding		A		T	Observatory

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-281	3.7.1.15.10.5	Safe Haven Mode Data Handling		A		T	Observatory
MR-282	3.7.1.16	Launch Vehicle Interface		A			Observatory
MR-283	3.7.2.1	Launch Vehicle		A			Observatory
MR-396	3.7.3.1.1	Orbit Maximum Z Excursion		A			Ground Segment
MR-398	3.7.3.1.3	Eclipse Prevention		A			Ground Segment
MR-285	3.7.3.2	Wavefront Sensing and Control Executive		A			Ground Segment
MR-286	3.7.3.3	Observatory Wavefront Maintenance		A			Ground Segment
MR-287	3.7.3.4	Ground Segment Overhead		A			Ground Segment
MR-288	3.7.3.5	Observatory Operations		A			Ground Segment
MR-399	3.7.3.5.1	Continuous Communication		A			Ground Segment
MR-289	3.7.3.5.2	Normal Operations			D		Ground Segment
MR-290	3.7.3.5.2.1	Unattended Operations			D		Ground Segment
MR-291	3.7.3.5.3	Mission Operations			D		Ground Sgement
MR-292	3.7.3.5.3.1	Execution of Mission Timeline			D		Ground Sgement
MR-293	3.7.3.5.3.2	Timeline Recovery and Modification			D		Ground Segment
MR-400	3.7.3.6	Science Instrument FOV Pointing Knowledge		A			Ground Segment
MR-294	3.7.3.7	Transfer Orbit and Operational Orbit Determination			D		Ground Segment
MR-296	3.7.3.8.1	Ground Master Image			D		Ground Segment
MR-297	3.7.3.8.2	Software Configuration Archive			D		Ground Segment
MR-298	3.7.3.8.3	Software Update			D		Ground Segment
MR-165	3.7.3.8.4	Mean Time to Repair		A		T	MSE
MR-299	3.7.3.9	Project Reference Data Base			D		Ground Segment
MR-300	3.7.3.9.1	Observatory Information Source			D		Ground

Requirement Number		Object Heading	I	A	D	T	Responsible Org
							Segment
MR-301	3.7.3.9.2	Integration and Test			D		Ground Segment
MR-302	3.7.3.9.3	Validation Prior to Use			D		Ground Segment
MR-307	3.7.3.10.1	Archive Catalog		A			Ground Segment
MR-308	3.7.3.10.2	Other Contents			D		Ground Segment
MR-309	3.7.3.10.3	Multiple Copies			D		Ground Segment
MR-310	3.7.3.10.4	Provision of Data to International Partners			D		Ground Segment
MR-311	3.7.3.10.5	Temporary Storage of Real-Time Telemetry			D		Ground Segment
MR-312	3.7.3.10.6	Processing Efficiency		A			Ground Segment
MR-313	3.7.3.10.7	Output Products			D		Ground Segment
MR-314	3.7.3.10.7.1	Product Format			D		Ground Segment
MR-315	3.7.3.10.7.2	Use of Up-to-Date Calibrations			D		Ground Segment
MR-316	3.7.3.10.8	Availability of New Data			D		Ground Segment
MR-317	3.7.3.10.8.1	Timeliness of Delivery				T	Ground Segment
MR-318	3.7.3.10.9	Archival Research			D		Ground Segment
MR-320	3.7.3.11.1	Health and Safety Protections			D		Ground Segment
MR-321	3.7.3.11.2	Deliberate Override			D		Ground Segment
MR-322	3.7.3.12	Real-Time Systems and Functions		A			Ground Segment
MR-323	3.7.3.12.1	Availability		A			Ground Segment
MR-324	3.7.3.12.2	Capability for Real-Time Commanding			D		Ground Segment
MR-325	3.7.3.12.3	Prevention of Mutual Interference			D		Ground Segment

Requirement Number		Object Heading	I	A	D	T	Responsible Org
MR-326	3.7.3.12.4	Primary and Backup Systems	I		D		Ground Segment
MR-327	3.7.3.12.5	Mission Critical Operations				T	Ground Segment
MR-328	3.7.3.12.6	Transfer of Non-Critical Operations				T	Ground Segment
MR-329	3.7.3.12.7	Test Support			D		Ground Segment
MR-330	3.7.3.12.8	S&OC Alternate Facility				T	Ground Segment
MR-331	3.7.3.12.9	Command Function Security		A			Ground Segment
MR-NEW1 (OBSR-288a)	3.7.3.12.9.1	Command Authentication				T	
MR-334	3.7.3.12.10	Command Uplink			D		Ground Segment
MR-335	3.7.3.12.11	Command Verification			D		Ground Segment
MR-336	3.7.3.12.12	Observatory Monitoring			D		Ground Segment
MR-337	3.7.3.12.13	Real-Time Telemetry Monitoring			D		Ground Segment
MR-338	3.7.3.12.14	Real-Time Engineering Data Forwarding				T	Ground Segment
MR-339	3.7.3.12.15	Stored Engineering Data Forwarding Start				T	Ground Segment
MR-401	3.7.3.12.16	Data Forwarding Data Rate		A			Ground Segment
MR-376	3.7.3.12.17	Stored Science Data Forwarding				T	Ground Segment
MR-377	3.7.3.12.18	Receipt of Uncompressed Recorded Engineering Data			D		Ground Segment
MR-412	3.7.2.12.19	Receipt of Compressed Science Data Volume		A			Ground Segment
MR-402	3.7.3.12.21	Ground Real Time Data Transfer		A			Ground Segment
MR-403	3.7.3.12.22	Ground Recorded Data Transmittal		A			Ground Segment
MR-343	3.7.3.13	Off-Line Systems and Functions			D		Ground

Requirement Number		Object Heading	I	A	D	T	Responsible Org
							Segment
MR-344	3.7.3.13.1	Science Proposal Support			D		Ground Segment
MR-345	3.7.3.13.2	Observation Modifications			D		Ground Segment
MR-347	3.7.3.13.3	Performance Trending			D		Ground Segment
MR-348	3.7.3.13.4	Calibration Trending Analysis			D		Ground Segment
MR-349	3.7.3.13.5	Observatory Subsystem Calibration			D		Ground Segment
MR-350	3.7.3.13.6	Observatory Telemetry Calibration			D		Ground Segment
MR-351	3.7.3.13.7	Simulators and Models	I		D		Ground Segment
MR-352	3.7.3.14	Ground Segment Communication Support For Normal Operations		A			Ground Segment
MR-353	3.7.3.14.1	Deep Space Network Antenna	I				Ground Segment
MR-354	3.7.3.14.2	S-Band Emergency Services		A			Ground Segment
MR-355	3.7.3.14.2.1	Response Time				T	Ground Segment
MR-356	3.7.3.14.2.2	Continuity of Service		A			Ground Segment
MR-357	3.7.3.14.3	Ka-Band Emergency Service		A			Ground Segment
MR-378	3.7.3.14.4	Ground Segment Support for Continuous Two-way Communication (S-Band)		A			Ground Segment
MR-413	3.7.3.14.5	Launch Phase Communications		A			Ground Segment
MR-234	3.7.3.14.6	Ground Segment Support for Continuous Communication (Ka-Band)		A			Ground Segment

APPENDIX A. ABBREVIATIONS AND ACRONYMS

ABBREVIATION/ ACRONYM	DEFINITION
A	Analysis
Arcmin	Minute of Arc
Arcsec	Second of Arc
ASTM	American Society of Testing and Materials
BER	Bit Error Rate
bps	Bits per second
C&DH	Command and Data Handling
CCR	Configuration Change Request
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
CFDP	CCSDS File Delivery Protocol
CM	Configuration Management
CMO	Configuration Management Office
COBE	Cosmic Background Explorer
COP	Command Operations Protocol
CSA	Canadian Space Agency
D	Demonstration
DIRBE	Diffuse Infrared Background Experiment
DSN	Deep Space Network
EELV	Evolved Expendable Launch Vehicle
ELV	Expendable Launch Vehicle
EOL	End of Life
EPS	Electrical Power Subsystem
ESA	European Space Agency
FGS	Fine Guidance Sensor
FGS-TF	Fine Guidance Sensor Tunable Filter
FOR	Field of Regard
FOV	Field of View
Gbps	Gigabits per second
GEVS-SE	General Environmental Verification Specification for STS and ELV Payloads
GSFC	Goddard Space Flight Center
HGA	High Gain Antenna
I	Inspection
IEEE	Institute of Electrical and Electronics Engineers
IRD	Interface Requirements Document
ISIM	Integrated Science Instrument Module
JWST	James Webb Space Telescope
K	Kelvin
Kbps	Kilobits per second

ABBREVIATION/ ACRONYM	DEFINITION
Kg	kilograms
LGA	Low Gain Antenna
L2	Second LaGrange Point
Mas/s	Millisecond of arc per second
Mbps	Megabits per second
MIRI	Mid-Infrared Instrument
Mjy/sr	Mega-Jansky per Steradian
MR	Mission Requirement
NASA	National Aeronautics and Space Administration
NIR	Near-Infrared
NIRCam	Near-Infrared Camera
NIRSpec	Near-Infrared Spectrograph
nJy	Nano-Jansky (10^{-35} $W/m^2/Hz$)
nm	nanometers
OPS	Operations
OTE	Optical Telescope Element
PI	Principal Investigator
PROC	Procedure
PSF	Point Spread Function
QE	Quantum Efficiency
R	Spectral Resolution ($\lambda/\Delta\lambda$, where λ is the central wavelength and $\Delta\lambda$, the filter bandwidth)
RF	Radio Frequency
RMS	Root Mean Square
RQMT	Requirement
RSS	Root Sum Square
S&OC	Science and Operations Center
S/N	Signal to Noise
SBC	Single Board Computer
SI	Science Instrument
Sr	Steradian
SSR	Solid State Recorder
STS	Space Transportation System
T	Test
TBD	To Be Determined
TBR	To Be Resolved
U.S.	United States
UTC	Coordinated Universal Time
VDC	Volts Direct Current
WFE	Wavefront Error
WFS&C	Wavefront Sensing and Control

APPENDIX B. TRACEABILITY MATRIX

Parent Requirement	Requirement	Child Requirement
	MR-92 3.1.4 Units	
L1-12 5.3.2 Orbit L1-11 5.3.1 DATE	MR-40 3.2.1.1.1 TRANSFER ORBIT	MR-294 3.7.3.7 Transfer Orbit and Operational Orbit Determination MR-283 3.7.2.1 Launch Vehicle MR-282 3.7.1.16 Launch Vehicle Interface MR-99 3.7.1.2.1 Observatory Mass Allocation
L1-12 5.3.2 Orbit L1-16 5.4.3 Thermal Environment	MR-41 3.2.1.1.2 Operational Orbit	MR-353 3.7.3.14.1 Deep Space Network Antenna MR-294 3.7.3.7 Transfer Orbit and Operational Orbit Determination MR-273 3.7.1.15.7 Fault Tolerance MR-272 3.7.1.15.6 Health and Safety Responsibility MR-239 3.7.1.15.1.11 Ranging MR-387 3.2.1.1.2.3 Eclipse Prevention MR-386 3.2.1.1.2.2 Orbit Maximum Y Excursion MR-385 3.2.1.1.2.1 Orbit Maximum Z Excursion OBS-56 3.2.1.1.1 Operational Orbit OBS-1941 3.2.1.1.6 Delta-Velocity Capability GS-021 3.2.1.1 Orbit
MR-41 3.2.1.1.2 Operational Orbit	MR-385 3.2.1.1.2.1 Orbit Maximum Z Excursion	MR-396 3.7.3.1.1 Orbit Maximum Z Excursion MR-388 3.7.1.1.2 Maximum Z Excursion FG-2307 3.4.5.2 Roll Bias Angle FG-2308 3.4.5.3 Environmental Torques
MR-41 3.2.1.1.2 Operational Orbit	MR-386 3.2.1.1.2.2 Orbit Maximum Y Excursion	MR-397 3.7.3.1.2 Orbit Maximum Y Excursion MR-389 3.7.1.1.3 Orbit Maximum Y Excursion

Parent Requirement	Requirement	Child Requirement
		FG-2307 3.4.5.2 Roll Bias Angle FG-2308 3.4.5.3 Environmental Torques
MR-41 3.2.1.1.2 Operational Orbit	MR-387 3.2.1.1.2.3 Eclipse Prevention	MR-398 3.7.3.1.3 Eclipse Prevention
L1-12 5.3.2 Orbit L1-11 5.3.1 Date	MR-42 3.2.1.1.3 Operational Orbit Transfer	OBS-57 3.2.1.1.2 Operational Orbit Transfer OBS-1941 3.2.1.1.6 Delta-Velocity Capability
L1-9 5.2.1 Lifetime	MR-44 3.2.1.2.1 Science Mission Lifetime	MR-336 3.7.3.12.12 Observatory Monitoring MR-320 3.7.3.11.1 Health and Safety Protections MR-288 3.7.3.5 Observatory Operations MR-278 3.7.1.15.10.2 Safe Mode Consumables MR-273 3.7.1.15.7 Fault Tolerance MR-272 3.7.1.15.6 Health and Safety Responsibility MR-269 3.7.1.15.4 Observatory Thermal Subsystem MR-261 3.7.1.15.2 Electrical Power Subsystem MR-168 3.7.1.12.1 Sun Damage MR-90 3.3.1 Thermal Design Margins MR-84 3.2.3.1 Single Failure MR-48 3.7.1.15.5 Propellant Lifetime MR-91 3.3.2 Calculated Heat Rejection Capacity Margins for Cryogenic Systems OBS-59 3.2.1.2.1 Science Mission Lifetime GS-022 3.2.1.2 Science Mission Lifetime
L1-9 5.2.1 Lifetime	MR-45 3.2.1.2.2 Commissioning Phase Duration	MR-78 3.2.1.10 Continuous Two-way Communication OBS-60 3.2.1.2.2 Comissioning Phase Duration

Parent Requirement	Requirement	Child Requirement
L1-10 5.2.2 Telemetry	MR-49 3.2.1.3 Real-time Data Efficiency	MR-238 3.7.1.15.1.10 Real-Time Data Downlink MR-382 3.7.1.11.13 Nominal Observatory Data Loss MR-142 3.7.1.11.7.1 Coordinated Universal Time Correlation Accuracy MR-79 3.2.1.12 Command Bit Error Rate MR-80 3.2.1.13 Telemetry Bit Error Rate MR-410 3.7.1.15.1.15 Real-Time Data Efficiency MR-402 3.7.3.12.19 Ground Real Time Data Transmittal GS-035 3.2.2.3 Real-time Data Delivery
L1-10 5.2.2 Telemetry	MR-50 3.2.1.4 Recorded Data Efficiency	MR-352 3.7.3.14 Ground Segment Communication Support For Normal Operations MR-237 3.7.1.15.1.8 Stored Data Downlink MR-236 3.7.1.15.1.7 Downlink of Uncompressed Recorded Engineering Data MR-382 3.7.1.11.13 Nominal Observatory Data Loss MR-130 3.7.1.11.3.1 Storage Capacity MR-381 3.2.1.14 Nominal Data Quality MR-403 3.7.3.12.22 Ground Recorded Data Transmittal MR-411 3.7.1.15.1.16 Recorded Data Efficiency GS-280 3.2.1.4.3 Stored Data Efficiency
L1-1 5.1.1.1 Density of Galaxies L1-2 5.1.1.2 Spectra of	MR-51 3.2.1.5 Sensitivity	MR-400 3.7.3.6 Science Instrument FOV Pointing Knowledge MR-226 3.7.1.14.4 Vignetting

Parent Requirement	Requirement	Child Requirement
Galaxies L1-14 5.4.2 Strehl Ratio L1-13 5.4.1 Telescope L1-15 5.4.3 Encircled Energy L1-3 5.1.1.3 Physical and Chemical Properties of Young Stellar Objects L1-5 5.1.2.1 Density of Galaxies L1-6 5.1.2.2 Spectra of Galaxies L1-7 5.1.2.3 Physical and Chemical Properties of Young Stellar Objects L1-16 5.4.4 Thermal Environment L1-17 5.5 BASELINE SCIENCE INSTRUMENTS REQUIREMENTS L1-18 5.5.1 Near-Infrared Camera L1-19 5.5.2 Near-Infrared Spectrograph L1-20 5.5.3 Mid-Infrared Instrument		MR-211 3.7.1.14.3 Optical Transmission MR-198 3.7.1.14.1 Primary Mirror Area MR-193 3.7.1.13.14 Common Focus MR-186 3.7.1.13.6 Spectroscopy Spectral Resolution MR-185 3.7.1.13.5 Imagery Spectral Bandwidths MR-369 3.7.1.13.3 Science Instruments and Guiders Allocated Field of View MR-364 3.7.1.12.17 Field of View Offsets, 20 - 45 Arcsec MR-374 3.7.1.12.16 Field of View Offsets, 2.0 - 20 Arcsec MR-181 3.7.1.12.15 Field of View Offsets, 0.5 - 2.0 Arc-second MR-182 3.7.1.12.14 Field of View Offsets, 0.0 - 0.5 Arc-second MR-177 3.7.1.12.10 Field of View Orientation MR-393 3.7.1.12.8 Absolute Pointing Knowledge MR-175 3.7.1.12.7 Science Instrument FOV Pointing Knowledge Data MR-174 3.7.1.12.6 Relative Offset Pointing Repeatability MR-125 3.2.1.6 Contamination Control MR-122 3.7.1.7.4 Stray Light From Thermal Emissions MR-121 3.7.1.7.3 Stray Light at Near-Infrared Wavelengths MR-116 3.7.1.7.2 Strehl Ratio for Mid-Infrared Instrument MR-110 3.7.1.7.1.1 Strehl Ratio MR-107 3.7.1.5 Wavelength Range MR-120 3.2.1.17 Field Distortion Uncertainty

Parent Requirement	Requirement	Child Requirement
		MR-113 3.7.1.7.1.2.1 24 Hour Encircled Energy Stability OBS-67 3.2.1.4.2 Sensitivity
MR-51 3.2.1.5 Sensitivity	MR-125 3.2.1.6 Contamination Control	OBS-263 3.3.8.1 Contamination Control
L1-15 5.4.3 Encircled Energy	MR-379 3.2.1.7 Pupil Imaging	MR-380 3.7.1.13.8 Pupil Imaging
L1-21 5.6 GROUND SYSTEM REQUIREMENTS	MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-129 3.7.1.11.3 On-Board Storage MR-188 3.7.1.13.9 Data Compression MR-134 3.7.1.11.3.2.2 Science Observation Identification MR-133 3.7.1.11.3.2.1 Science Exposure Identification MR-130 3.7.1.11.3.1 Storage Capacity MR-412 3.7.3.12.19 Receipt of Compressed Science Data Volume MR-409 3.7.1.15.1.9 Downlink of Compressed Science Data Volume GS-032 3.2.1.4.1 Receipt of Compressed Science Data Volume OBS-1747 3.2.1.6.5.1 Downlink of Compressed Science Data Volume FG-1919 3.3.1.1.1.1 Recorded Science Data Volume
L1-10 5.2.2 Telemetry	MR-77 3.2.1.9 Normal Operations	MR-357 3.7.3.14.3 Ka-Band Emergency Service MR-356 3.7.3.14.2.2 Continuity of Service MR-355 3.7.3.14.2.1 Response Time MR-354 3.7.3.14.2 S-Band Emergency Services MR-352 3.7.3.14 Ground Segment Communication Support For Normal Operations MR-377 3.7.3.12.18 Receipt of Uncompressed Recorded Engineering Data MR-330 3.7.3.12.8 S&OC Alternate Facility MR-323 3.7.3.12.1 Availability MR-273 3.7.1.15.7 Fault Tolerance

Parent Requirement	Requirement	Child Requirement
		MR-272 3.7.1.15.6 Health and Safety Responsibility MR-232 3.7.1.15.1.1 Communication Operations MR-145 3.7.1.11.8.1 Capability for Real-Time Commanding MR-128 3.7.1.11.2 Command Authentication MR-391 3.7.1.10 Normal Operations MR-82 3.2.2.1 Deep Space Network MR-78 3.2.1.10 Continuous Two-way Communication MR-331 3.7.3.12.9 Command Function Security MR-NEW1 (OBSR-228a) 3.7.3.12.9.1 Command Authentication MR-334 3.7.3.12.10 Command Uplink MR-335 3.7.3.12.11 Command Verification MR-405 3.2.1.11 Launch Phase Communications MR-250 3.7.1.15.1.13.3 Low Rate Downlink MR-143 3.7.1.11.7.2 Coordinated Universal Time Clock Maintenance FG-1822 3.5.1.3 Orbit Station Keeping FG-1825 3.5.3.1 Communications Contact Frequency, Normal Operations

Parent Requirement	Requirement	Child Requirement
MR-77 3.2.1.9 Normal Operations MR-45 3.2.1.2.2 Commissioning Phase Duration	MR-78 3.2.1.10 Continuous Two-way Communication	MR-234 3.7.3.14.6 Ground Segment Support for Continuous Communication (Ka-Band) MR-378 3.7.3.14.4 Ground Segment Support for Continuous Two-way Communication (S-Band) MR-399 3.7.3.5.1 Continuous Communication MR-395 3.7.1.15.1.2 Continuous Two-Way Communication MR-232 3.7.1.15.1.1 Communication Operations MR-334 3.7.3.12.10 Command Uplink MR-335 3.7.3.12.11 Command Verification FG-1816 3.5.2 S-Band Link Operation During Commissioning FG-1820 3.5.1.1 Orbit Injection FG-1821 3.5.1.2 Post-Separation Activities
MR-77 3.2.1.9 Normal Operations	MR-405 3.2.1.11 LAUNCH PHASE COMMUNICATIONS	MR-407 3.7.1.15.1.3 Launch Phase Communications MR-413 3.7.3.14.5 Launch Phase Communications
MR-49 3.2.1.3 Real-time Data Efficiency	MR-79 3.2.1.12 Command Bit Error Rate	MR-241 3.7.1.15.1.12.1 Command Uplink MR-235 3.7.1.15.1.6 Link Margins GS-293 3.2.10.6.6 Command Bit Error Rate OBS-126 3.2.1.6.3.1 Command Bit Error Rate FG-1902 3.1.3.3.5 Command Bit Error Rate

Parent Requirement	Requirement	Child Requirement
MR-49 3.2.1.3 Real-time Data Efficiency	MR-80 3.2.1.13 Telemetry Bit Error Rate	MR-249 3.7.1.15.1.13.2 Pseudo-Randomization of Data MR-248 3.7.1.15.1.13.1 Downlink Data Encoding MR-235 3.7.1.15.1.6 Link Margins GS-295 3.2.10.7.9 Telemetry Bit Error Rate OBS-1354 3.2.1.6.3.2 Telemetry Bit Error Rate FG-1887 3.2.1.6 Ka-Band RF Bit Error Rate FG-1896 3.1.3.2.8 Telemetry Bit Error Rate
MR-50 3.2.1.4 Recorded Data Efficiency	MR-381 3.2.1.14 Nominal Data Quality	
L1-15 5.4.3 Encircled Energy	MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control	MR-349 3.7.3.13.5 Observatory Subsystem Calibration MR-286 3.7.3.3 Observatory Wavefront Maintenance MR-285 3.7.3.2 Wavefront Sensing and Control Executive MR-228 3.7.1.14.5.1 Optical Telescope Element Unvignetted Field of View Wavefront Error MR-192 3.7.1.13.13 Fine Guidance Sensor Operations MR-176 3.7.1.12.9 Field Orientation Knowledge MR-173 3.7.1.12.5 Fine Guidance Pointing Accuracy MR-172 3.7.1.12.4 Observatory Optical Telescope Element Boresight Coarse Pointing Accuracy MR-170 3.7.1.12.2.1 Guiding Capability MR-123 3.7.1.8 Image Based Wavefront Sensing

Parent Requirement	Requirement	Child Requirement
L1-4 5.1.1.4 Observing Time L1-8 5.1.2.4 Observing Time	MR-102 3.2.1.16 JWST SYSTEM EFFICIENCY	MR-287 3.7.3.4 Ground Segment Overhead MR-171 3.7.1.12.2.2 Guide Star Availability MR-106 3.7.1.4.4 Continuous Visibility Zone MR-105 3.7.1.4.3 Consecutive Coverage MR-104 3.7.1.4.2 Field of Regard MR-103 3.7.1.4.1 Annual Coverage MR-390 3.7.1.3 Observatory Overhead
MR-51 3.2.1.5 Sensitivity	MR-120 3.2.1.17 Field Distortion Uncertainty	MR-349 3.7.3.13.5 Observatory Subsystem Calibration OBS-93 3.2.1.4.6.3 Field Distortion Uncertainty
MR-77 3.2.1.9 Normal Operations	MR-82 3.2.2.1 Deep Space Network	MR-353 3.7.3.14.1 Deep Space Network Antenna MR-408 3.7.1.15.1.4 Deep Space Network Compatibility FG-120 3.1.5 Ground Station FG-795 3.1.5.1 Ka-Band Ground Station Antenna FG-796 3.1.5.2 S-Band Ground Station Antenna FG-1888 3.1.2.7 Ka-Band Link Weather Availability FG-1897 3.1.3.2.9 Telemetry Link Weather Availability FG-1903 3.1.3.3.6 Command Link Weather Availability
MR-44 3.2.1.2.1 Science Mission Lifetime	MR-84 3.2.3.1 Single Failure	MR-275 3.7.1.15.9 Cross Strapping MR-274 3.7.1.15.8 Fault Propagation MR-268 3.7.1.15.3.1 Mechanisms OBS-207 3.2.3.6 Single Failure
MR-44 3.2.1.2.1 Science	MR-90 3.3.1 Thermal Design	OBS-171 3.3.5.1 Thermal Design

Parent Requirement	**Requirement**	**Child Requirement**
Mission Lifetime	Margins	Margins
MR-44 3.2.1.2.1 Science Mission Lifetime	MR-91 3.3.2 Calculated Heat Rejection Capacity Margins for Cryogenic Systems	OBS-175 3.3.5.2 Calculated Heat Rejection Capacity Margins for Cryogenic Systems
MR-41 3.2.1.1.2 Operational Orbit	MR-406 3.7.1.1.1 Orbit Range	OBS-1938 3.2.1.1.3 Orbit Range
MR-385 3.2.1.1.2.1 Orbit Maximum Z Excursion	MR-388 3.7.1.1.2 Maximum Z Excursion	OBS-1940 3.2.1.1.5 Maximum Z Excursion FG-2306 3.4.5.1 Momentum Storage Capacity FG-2316 3.4.6.4 Pointing Accuracy
MR-386 3.2.1.1.2.2 Orbit Maximum Y Excursion	MR-389 3.7.1.1.3 Orbit Maximum Y Excursion	OBS-1939 3.2.1.1.4 Orbit Maximum Y Excursion FG-2306 3.4.5.1 Momentum Storage Capacity FG-2316 3.4.6.4 Pointing Accuracy
MR-40 3.2.1.1.1 Transfer Orbit	MR-99 3.7.1.2.1 Observatory Mass Allocation	MR-184 3.7.1.13.1 INTEGRATED SCIENCE INSTRUMENT MODULE MASS MR-100 3.7.1.2.2 Mission Unique Launch Vehicle Accommodation OBS-199 3.2.2.2.1 Observatory mass Allocation
MR-99 3.7.1.2.1 Observatory Mass Allocation	MR-100 3.7.1.2.2 Mission Unique Launch Vehicle Accommodation	OBS-200 3.2.2.2.1.1 Mission-Unique Launch Vehicle Accommodation

Parent Requirement	Requirement	Child Requirement
MR-102 3.2.1.16 JWST System Efficiency	MR-390 3.7.1.3 Observatory Overhead	MR-277 3.7.1.15.10.1 Safe Mode Hierarchy MR-232 3.7.1.15.1.1 Communication Operations MR-394 3.7.1.13.18 ISIM Overhead MR-194 3.7.1.13.15 Restrictions on Optical Telescope Element Adjustment MR-192 3.7.1.13.13 Fine Guidance Sensor Operations MR-180 3.7.1.12.13 Medium Maneuver Slew Rate MR-179 3.7.1.12.12 Small Maneuver Slew Rate MR-178 3.7.1.12.11 Re-pointing MR-365 3.7.1.12.2.3 Single Point Failure MR-392 3.7.1.11.11.4.2 Volatile Memory Reloading MR-166 3.7.1.11.11.4.1 In-Flight Updates MR-163 3.7.1.11.11.3 Flight Software Common Programming Language MR-162 3.7.1.11.11.2 Common Command and Data Handling Operating System MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations MR-159 3.7.1.11.10.1 Data Playback MR-135 3.7.1.11.3.3 Simultaneous Onboard Storage MR-368 3.7.1.6.1 Spacecraft and Optical Telescope Element Reliability MR-177 3.7.1.12.10 Field of View Orientation OBS-181 3.2.1.9.1 Observatory Overhead
MR-102 3.2.1.16 JWST System Efficiency	MR-103 3.7.1.4.1 Annual Coverage	OBS-79 3.2.1.5.8.1 Annual Coverage
MR-102 3.2.1.16 JWST System Efficiency	MR-104 3.7.1.4.2 Field of Regard	OBS-78 3.2.1.5.8.2 Field of Regard

Parent Requirement	**Requirement**	**Child Requirement**
MR-102 3.2.1.16 JWST System Efficiency	MR-105 3.7.1.4.3 Consecutive Coverage	OBS-80 3.2.1.5.8.3 Consecutive Coverage
MR-102 3.2.1.16 JWST System Efficiency	MR-106 3.7.1.4.4 Continuous Visibility Zone	OBS-190 3.2.1.5.8.4 Continuous Visibility Zone
MR-51 3.2.1.5 Sensitivity	MR-107 3.7.1.5 Wavelength Range	OBS-66 3.2.1.4.1 Wavelength Range
MR-390 3.7.1.3 Observatory Overhead	MR-368 3.7.1.6.1 Spacecraft and Optical Telescope Element Reliability	OBS-1692 3.2.3.1 Spacecraft and Optical Telescope Element Reliability
MR-394 3.7.1.13.18 ISIM Overhead	MR-383 3.7.1.6.2 ISIM Reliability	OBS-1946 3.2.3.2 ISIM Reliability
MR-51 3.2.1.5 Sensitivity	MR-110 3.7.1.7.1.1 Strehl Ratio	MR-170 3.7.1.12.2.1 Guiding Capability OBS-1607 3.2.1.4.6.1.1 Strehl Ratio
MR-51 3.2.1.5 Sensitivity	MR-113 3.7.1.7.1.2.1 24 Hour Encircled Energy Stability	MR-114 3.7.1.7.1.3.1.1 Conditions MR-115 3.7.1.7.1.2.2 Encircled Energy Long Term Stability OBS-88 3.2.1.4.6.1.2.1 24-Hour Encircled Energy Stability
MR-113 3.7.1.7.1.2.1 24 Hour Encircled Energy Stability	MR-114 3.7.1.7.1.2.1.1 Conditions	OBS-89 3.2.1.4.6.1.2.1.1 Conditions
MR-113 3.7.1.7.1.2.1 24 Hour Encircled Energy Stability	MR-115 3.7.1.7.1.2.2 Encircled Energy Long Term Stability	OBS-90 3.2.1.4.6.1.2.2 Long Term Encircled Energy Stability OBS-1832 3.2.1.3.4 Time Period Between OTE Adjustments
MR-51 3.2.1.5 Sensitivity	MR-116 3.7.1.7.2 Strehl Ratio for Mid-Infrared Instrument	OBS-107 3.2.1.4.6.2 Strehl Ration for Mid-Infrared Instrument
MR-51 3.2.1.5 Sensitivity	MR-121 3.7.1.7.3 Stray Light at Near-Infrared Wavelengths	OBS-94 3.2.1.4.6.4.1 Stray Light at Visible and Near-Infrared Wavelengths
MR-51 3.2.1.5 Sensitivity	MR-122 3.7.1.7.4 Stray Light From Thermal Emissions	OBS-95 3.2.1.4.6.4.2 Stray Light From Thermal Emissions
MR-372 3.7.1.12.3 Moving Target Tracking	MR-371 3.7.1.7.5.1 Strehl Ratio For Moving Targets	

Parent Requirement	Requirement	Child Requirement
MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control	MR-123 3.7.1.8 Image Based Wavefront Sensing	MR-187 3.7.1.13.7 Wavefront Sensing MR-124 3.7.1.9 Wavefront Error Correction Capability OBS-63 3.2.1.3.1 Image Based Wavefront Sensing
MR-123 3.7.1.8 Image Based Wavefront Sensing	MR-124 3.7.1.9 Wavefront Error Correction Capability	GS-296 3.2.12.1 Wavefront Error Correction Capability OBS-108 3.2.1.3.3 Wavefront Error Correction Capability FG-2327 3.4.7.1 Time Period Between OTE Adjustments
MR-77 3.2.1.9 Normal Operations	MR-391 3.7.1.10 Normal Operations	OBS-1744 3.2.1.6.1.2 Normal Operations
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-127 3.7.1.11.1 Observatory Event Logs	OBS-999 3.2.1.10.8 Observatory Event Logs FG-2130 3.3.6 ISIM Flight Software Event Messages
MR-77 3.2.1.9 Normal Operations Golden Rules	MR-128 3.7.1.11.2 Command Authentication	OBS-1760 3.2.1.7.1 Command Authentication
MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-129 3.7.1.11.3 On-Board Storage	OBS-1771 3.2.1.7.2 On-Board Data Storage FG-1812 3.3.3.1 Spacecraft Element Memory Load FG-2066 3.3.3.3 ICDH Memory Load and Dump FG-2184 3.3.3.2 Spacecraft Element Memory Dump FG-2233 3.2.4.1 SSR Science Data Format FG-2256 3.3.3.3.1 ICDH Table Load Format FG-2257 3.3.3.3.2 ICDH Contiguous Memory Loads FG-2258 3.3.3.3.3 ICDH Segmented Memory Loads FG-2259 3.3.3.3.4 ICDH Table Dump CCSDS Packet Format FG-2260 3.3.3.3.5 ICDH Memory

Parent Requirement	Requirement	Child Requirement
		Dump CCSDS Packet Format FG-2292 3.3.3.4.1 ICDH File Load FG-2293 3.3.3.4.2 ICDH File Dump FG-2294 3.3.3.4.3 ICDH CFDP Metadata Command Packet Format FG-2295 3.3.3.4.4 ICDH CFDP File Data Command Packet Format FG-2296 3.3.3.4.5 ICDH CFDP End-of-File (No Error) Command Packet Format FG-2297 3.3.3.4.6 ICDH CFDP End-of-File (Cancel) Command Packet Format FG-2298 3.3.3.4.7 ICDH CFDP Metadata Telemetry Packet Format FG-2299 3.3.3.4.8 ICDH CFDP File Data Telemetry Packet Format FG-2300 3.3.3.4.9 ICDH CFDP End-of-File (No Error) Telemetry Packet Format FG-2301 3.3.3.4.10 ICDH CFDP End-of-Life (Cancel) Telemetry Packet Format FG-2302 3.3.3.4.11 ICDH CFDP PDU CRC Algorithm
MR-50 3.2.1.4 Recorded Data Efficiency MR-76 3.2.1.8 Downlink of Compressed Science Data Volume MR-236 3.7.1.15.1.7 Downlink of Uncompressed Recorded Engineering Data	MR-130 3.7.1.11.3.1 Storage Capacity	OBS-1772 3.2.1.7.2.1 Storage Capacity
MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-133 3.7.1.11.3.2.1 Science Exposure Identification	GS-281 3.2.3.3 Science Exposure Identification OBS-137 3.2.1.7.2.3.1 Science Exposure Identification
MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-134 3.7.1.11.3.2.2 Science Observation Identification	GS-282 3.2.3.4 Science Observation Identification OBS-138 3.2.1.7.2.3.2 Science

Parent Requirement	Requirement	Child Requirement
		Observation Identification
MR-390 3.7.1.3 Observatory Overhead	MR-135 3.7.1.11.3.3 Simultaneous Onboard Storage	MR-137 3.7.1.11.4 Common Data Bus, Point to Point, and Power Interfaces MR-281 3.7.1.15.10.5 Safe Haven Mode Data Handling OBS-1774 3.2.1.7.2.2 Simultaneous On-board Storage
MR-135 3.7.1.11.3.3 Simultaneous Onboard Storage	MR-137 3.7.1.11.4 Common Data Bus, Point to Point, and Power Interfaces	OBS-132 3.2.1.7.3 Common Data Bus, Point to Point, and Power Interfaces
GSFC-STD-1000 3.07	MR-138 3.7.1.11.5 Processor Utilization	OBS-134 3.2.1.7.4 Processor Utilization
GSFC-STD-1000 3.07	MR-139 3.7.1.11.6 Local and External Data Bus Utilization	OBS-135 3.2.1.7.5 Local and External Data Bus Utilization
MR-49 3.2.1.3 Real-time Data Efficiency	MR-142 3.7.1.11.7.1 Coordinated Universal Time Correlation Accuracy	GS-288 3.2.7.3.1 Coordinated UTC Accuracy OBS-1602 3.2.1.7.8.1 Time Tage Generation OBS-1776 3.2.1.7.8.2 Coordinated Universal Time Correlation Accuracy FG-960 3.3.4.4.1 Time Correlation Method FG-1546 3.3.4.4.2 Time Correlation Accuracy
MR-49 3.2.1.3 Real-time Data Efficiency	MR-143 3.7.1.11.7.2 Coordinated Universal Time Clock Maintenance	OBS-1777 3.2.1.7.8.3 Coordinated Universal Time Clock Maintenance FG-2303 3.3.4.5.1 Observatory time stamp data packet FG-2304 3.3.4.5.2 Ground Segment time Maintenance
MR-77 3.2.1.9 Normal Operations	MR-145 3.7.1.11.8.1 Capability for Real-Time Commanding	MR-324 3.7.3.12.2 Capability for Real-Time Commanding MR-146 3.7.1.11.8.2 Prevention of Mutual Interference OBS-141 3.2.1.7.9.1 Capability for Real-Time Commanding
MR-145 3.7.1.11.8.1 Capability for Real-Time Commanding	MR-146 3.7.1.11.8.2 Prevention of Mutual Interference	OBS-142 3.2.1.7.9.2 Prevention of Mutual Interference

Parent Requirement	Requirement	Child Requirement
MR-272 3.7.1.15.6 Health and Safety Responsibility	MR-147 3.7.1.11.8.3 Command Safety	MR-149 3.7.1.11.8.5 Report Verified Commands MR-152 3.7.1.11.8.8 Report Executed Commands MR-151 3.7.1.11.8.7 Report Validated Commands MR-150 3.7.1.11.8.6 Command Validation MR-148 3.7.1.11.8.4 Command Verification OBS-121 3.2.1.8.8 Command Safety
MR-147 3.7.1.11.8.3 Command Safety	MR-148 3.7.1.11.8.4 Command Verification	OBS-144 3.2.1.7.9.3.1 Command Verification
MR-147 3.7.1.11.8.3 Command Safety	MR-149 3.7.1.11.8.5 Report Verified Commands	OBS-1350 3.2.1.7.9.3.2 Report Verified Commands FG-2252 3.3.1.1.3.1 Verified/Validated Command Reporting
MR-147 3.7.1.11.8.3 Command Safety	MR-150 3.7.1.11.8.6 Command Validation	OBS-145 3.2.1.7.9.3.3 Command Validation
MR-147 3.7.1.11.8.3 Command Safety	MR-151 3.7.1.11.8.7 Report Validated Commands	OBS-1351 3.2.1.7.9.3.4 Report Validated Commands FG-2252 3.3.1.1.3.1 Verified/Validated Command Reporting
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations MR-147 3.7.1.11.8.3 Command Safety	MR-152 3.7.1.11.8.8 Report Executed Commands	OBS-146 3.2.1.7.9.3.5 Report Executed Commands
MR-272 3.7.1.15.6 Health and Safety Responsibility	MR-153 3.7.1.11.8.9 Command Rejection	OBS-147 3.2.1.7.9.3.6 Command Rejection FG-2253 3.3.1.1.3.2 Rejected Command Reporting
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-156 3.7.1.11.9.1 Parallel Operations	MR-191 3.7.1.13.12 Science Instrument Operations OBS-182 3.2.1.9.4 Parallel Operations
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-157 3.7.1.11.9.2 Autonomous Operation	OBS-113 3.2.1.9.5 Autonomous Operations
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-158 3.7.1.11.9.3 Observatory Replan Accommodation	OBS-1801 3.2.1.9.2 Observatory Replan Accommodation
MR-390 3.7.1.3 Observatory	MR-159 3.7.1.11.10.1 Data	MR-375 3.7.1.11.10.2 Interleave

Parent Requirement	Requirement	Child Requirement
Overhead	Playback	Real-time with Recorded Data OBS-1522 3.2.1.7.7.1 Data Playback
MR-159 3.7.1.11.10.1 Data Playback	MR-375 3.7.1.11.10.2 Interleave Real-time with Recorded Data	GS-291 3.2.10.4 Interleaved Data OBS-1775 3.2.1.7.7.2 Interleave Real-Time with Recorded Data FG-1917 3.3.1.1.1 ka-Ban Downlink Usage
MR-390 3.7.1.3 Observatory Overhead	MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-190 3.7.1.13.11 Event Driven Execution MR-158 3.7.1.11.9.3 Observatory Replan Accommodation MR-157 3.7.1.11.9.2 Autonomous Operation MR-156 3.7.1.11.9.1 Parallel Operations MR-152 3.7.1.11.8.8 Report Executed Commands MR-127 3.7.1.11.1 Observatory Event Logs OBS-162 3.2.1.10.3 Event-Driven Observatory Operations OBS-1612 3.2.1.10.2 Observatory Flight Software Execution
MR-390 3.7.1.3 Observatory Overhead	MR-162 3.7.1.11.11.2 Common Command and Data Handling Operating System	OBS-151 3.2.1.10.4 Common Command and Data Handling Operating System
MR-390 3.7.1.3 Observatory Overhead	MR-163 3.7.1.11.11.3 Flight Software Common Programming Language	OBS-163 3.2.1.10.5 Flight Software Common Programming Language
MR-390 3.7.1.3 Observatory Overhead	MR-166 3.7.1.11.11.4.1 In-Flight Updates	OBS-161 3.2.1.10.6.1 In-Flight Updates OBS-1611 3.2.1.10.1 Observatory Flight Software Storage
MR-390 3.7.1.3 Observatory Overhead	MR-392 3.7.1.11.11.4.2 Volatile Memory Reloading	OBS-1945 3.2.1.10.6.2 Volatile Memory Unloading
GSFC-STD-1000 3.07	MR-366 3.7.1.11.12 Memory Margin	OBS-1358 3.2.1.7.6 Memory Margin

Parent Requirement	Requirement	Child Requirement
MR-50 3.2.1.4 Recorded Data Efficiency MR-49 3.2.1.3 Real-time Data Efficiency	MR-382 3.7.1.11.13 Nominal Observatory Data Loss	OBS-1943 3.2.1.7.13 Nominal Observatory Data Loss
MR-44 3.2.1.2.1 Science Mission Lifetime	MR-168 3.7.1.12.1 Sun Damage	OBS-81 3.2.1.5.8.6 Sun Damage FG-2318 3.4.6.6 MCC-1 Fault Protection, Ground Segment
MR-110 3.7.1.7.1.1 Strehl Ratio MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control	MR-170 3.7.1.13.2.1 Guiding Capability	MR-192 3.7.1.13.13 Fine Guidance Sensor Operations MR-171 3.7.1.12.2.2 Guide Star Availability OBS-179 3.2.1.9.6.1 Guiding Capability
MR-170 3.7.1.12.2.1 Guiding Capability MR-102 3.2.1.16 JWST System Efficiency	MR-171 3.7.1.12.2.2 Guide Star Availability	MR-369 3.7.1.13.3 Science Instruments and Guiders Allocated Field of View GS-283 3.2.3.5 Guide Star Availability OBS-180 3.2.1.9.6.2 Guide Star Availability
MR-390 3.7.1.3 Observatory Overhead	MR-365 3.7.1.12.2.3 Single Point Failure	OBS-1802 3.2.1.9.6.3 Single Point Failure
	MR-372 3.7.1.12.3 Moving Target Tracking	MR-371 3.7.1.7.5.1 Strehl Ratio For Moving Targets
MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control	MR-172 3.7.1.12.4 Observatory Optical Telescope Element Boresight Coarse Pointing Accuracy	OBS-186 3.2.1.5.1 Observatory Optical Telescope Element Boresight Coarse Pointing Accuracy
MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control	MR-173 3.7.1.12.5 Fine Guidance Pointing Accuracy	OBS-187 3.2.1.5.2 Fine Guidance Pointing Accuracy
MR-51 3.2.1.5 Sensitivity	MR-174 3.7.1.12.6 Relative Offset Pointing Repeatability	OBS-188 3.2.1.5.2 Relative Offset Pointing Repeatability
MR-51 3.2.1.5 Sensitivity	MR-175 3.7.1.12.7 Science Instrument FOV Pointing Knowledge Data	OBS-189 3.2.1.5.4 Science Instrument Field of View Pointing Knowledge Data
MR-51 3.2.1.5 Sensitivity	MR-393 3.7.1.12.8 Absolute Pointing Knowledge	
MR-384 3.2.1.15 Image-Based Wavefront Sensing and	MR-176 3.7.1.12.9 Field Orientation Knowledge	OBS-379 3.2.1.5.5 Field Orientation Control

Parent Requirement	Requirement	Child Requirement
Control		
MR-51 3.2.1.5 Sensitivity MR-390 3.7.1.3 Observatory Overhead	MR-177 3.7.1.12.10 Field of View Orientation	OBS-380 3.2.1.5.8.5 Field of View Orientation
MR-390 3.7.1.3 Observatory Overhead	MR-178 3.7.1.12.11 Re-pointing	OBS-191 3.2.1.5.6.3 Repointing OBS-1814 3.2.2.2.4 Moments of Inertia OBS-1834 3.2.2.2.3 Deployed Center of Mass
MR-390 3.7.1.3 Observatory Overhead	MR-179 3.7.1.12.12 Small Maneuver Slew Rate	OBS-192 3.2.1.5.6.1 Small Maneuver Slew Rate
MR-390 3.7.1.3 Observatory Overhead	MR-180 3.7.1.12.13 Medium Maneuver Slew Rate	OBS-1160 3.2.1.5.6.2 Medium Maneuver Slew Rate
MR-51 3.2.1.5 Sensitivity	MR-182 3.7.1.12.14 Field of View Offsets, 0.0 - 0.5 Arc-second	OBS-194 3.2.1.5.7.1 Field of View Offsets, 0.0 – 0.5 Arcseconds
MR-51 3.2.1.5 Sensitivity	MR-181 3.7.1.12.15 Field of View Offsets, 0.5 - 2.0 Arc-second	OBS-1685 3.2.1.5.7.2 Field of View Offsets, 0.5 – 2.0 Arcseconds
MR-51 3.2.1.5 Sensitivity	MR-374 3.7.1.12.16 Field of View Offsets, 2.0 - 20 Arcsec	OBS-193 3.2.1.5.7.3 Field of View Offsets, 2.0 – 20 Arcseconds
MR-51 3.2.1.5 Sensitivity	MR-364 3.7.1.12.17 Field of View Offsets, 20 - 45 Arcsec	OBS-1161 3.2.1.5.7.4 Field of View Offsets, 20 – 45 Arcseconds
MR-99 3.7.1.2.1 Observatory Mass Allocation	MR-184 3.7.1.13.1 Integrated Science Instrument Module Mass	OBS-1812 3.2.2.2.1.2 Integrated Science Instrument Module Mass
MR-261 3.7.1.15.2 Electrical Power Subsystem	MR-373 3.7.1.13.2 Integrated Science Instrument Module Power Allocation	OBS-1811 3.2.1.11.5 Integrated Science Instrument Module Average Power Allocation
MR-171 3.7.1.12.2.2 Guide Star Availability MR-51 3.2.1.5 Sensitivity	MR-369 3.7.1.13.3 Science Instruments and Guiders Allocated Field of View	MR-199 3.7.1.14.2 Optical Telescope Element Field of View MR-370 3.7.1.13.4 Science Instruments and Guiders Field of View OBS-1734 3.2.1.4.4.2 Science Instruments and FGS-Guider Allocated Field of View
MR-369 3.7.1.13.3 Science Instruments and Guiders Allocated Field of View	MR-370 3.7.1.13.4 Science Instruments and Guiders Field of View	OBS-96 3.2.1.4.4.3 Science Instruments and FGS-Guider Field of View
MR-51 3.2.1.5 Sensitivity	MR-185 3.7.1.13.5 Imagery Spectral Bandwidths	OBS-1738 3.2.1.4.5.1 Imagery Spectral Resolution OBS-2004 3.7.3.1.3.7.8 Centroid Data

Parent Requirement	Requirement	Child Requirement
		Availability during FGS Track to Fine Guide Transition
MR-51 3.2.1.5 Sensitivity	MR-186 3.7.1.13.6 Spectroscopy Spectral Resolution	OBS-1739 3.2.1.4.5.2 Spectroscopy Spectral Resolution
MR-123 3.7.1.8 Image Based Wavefront Sensing	MR-187 3.7.1.13.7 Wavefront Sensing	OBS-1731 3.2.1.3.2 Wavefront Sensing
MR-379 3.2.1.7 Pupil Imaging	MR-380 3.7.1.13.8 Pupil Imaging	OBS-1942 3.2.1.3.5 Pupil Imaging
MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-188 3.7.1.13.9 Data Compression	MR-189 3.7.1.13.10 Data Compression Bypass OBS-1797 3.2.1.7.11 Data Compression
MR-188 3.7.1.13.9 Data Compression	MR-189 3.7.1.13.10 Data Compression Bypass	OBS-1798 3.2.1.7.12 Data Comperssion Bypass
MR-161 3.7.1.11.11.1 Event-Driven Observatory Operations	MR-190 3.7.1.13.11 Event Driven Execution	OBS-184 3.2.1.9.3 Event-Driven Execution
MR-156 3.7.1.11.9.1 Parallel Operations	MR-191 3.7.1.13.12 Science Instrument Operations	OBS-1805 3.2.1.9.9.1 Science Instrument Operations
MR-170 3.7.1.12.2.1 Guiding Capability MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control MR-390 3.7.1.3 Observatory Overhead	MR-192 3.7.1.13.13 Fine Guidance Sensor Operations	OBS-1806 3.2.1.9.9.2 Fine Guidance Sensor Operations
MR-51 3.2.1.5 Sensitivity	MR-193 3.7.1.13.14 Common Focus	OBS-1807 3.2.1.9.9.3 Common Focus
MR-390 3.7.1.3 Observatory Overhead	MR-194 3.7.1.13.15 Restrictions on Optical Telescope Element Adjustment	OBS-1808 3.2.1.9.9.4 Restrictions on Optical Telescope Element Adjustment
MR-272 3.7.1.15.6 Health and Safety Responsibility	MR-195 3.7.1.13.16 Science Instrument System Monitoring	OBS-1796 3.2.1.7.10 Science Instrument System Monitoring
MR-272 3.7.1.15.6 Health and Safety Responsibility	MR-196 3.7.1.13.17 Integrated Science Instrument Module Safe Mode	OBS-1799 3.2.1.8.2 Integrated Science Instrument Module Safe Mode
MR-390 3.7.1.3 Observatory Overhead	MR-394 3.7.1.13.18 ISIM Overhead	MR-383 3.7.1.6.2 ISIM Reliability OBS-1944 3.2.1.9.1.1 ISIM Overhead
MR-51 3.2.1.5 Sensitivity	MR-198 3.7.1.14.1 Primary Mirror Area	OBS-1815 3.2.2.2.5 Primary Mirror Area

Parent Requirement	Requirement	Child Requirement
MR-369 3.7.1.13.3 Science Instruments and Guiders Allocated Field of View	MR-199 3.7.1.14.2 Optical Telescope Element Field of View	MR-228 3.7.1.14.5.1 Optical Telescope Element Unvignetted Field of View Wavefront Error OBS-1733 3.2.1.4.4.1 Optical Telescope Element Field of View
MR-51 3.2.1.5 Sensitivity	MR-211 3.7.1.14.3 Optical Transmission	OBS-102 3.2.1.4.3 Optical Transmission
MR-51 3.2.1.5 Sensitivity	MR-226 3.7.1.14.4 Vignetting	MR-228 3.7.1.14.5.1 Optical Telescope Element Unvignetted Field of View Wavefront Error OBS-1003 3.2.1.4.8 Vignetting
MR-384 3.2.1.15 Image-Based Wavefront Sensing and Control MR-226 3.7.1.14.4 Vignetting MR-199 3.7.1.14.2 Optical Telescope Element Field of View	MR-228 3.7.1.14.5.1 Optical Telescope Element Unvignetted Field of View Wavefront Error	OBS-1599 3.2.1.4.7.1 Optical Telescope Element Unvignetted Field of View Wavefront Error
MR-77 3.2.1.9 Normal Operations MR-390 3.7.1.3 Observatory Overhead MR-78 3.2.1.10 Continuous Two-way Communication	MR-232 3.7.1.15.1.1 Communication Operations	MR-259 3.7.1.15.1.14.1 Commanding MR-256 3.7.1.15.1.13.4 High Rate Downlink MR-245 3.7.1.15.1.12.5 High Rate Command Uplink MR-244 3.7.1.15.1.12.4 Medium Rate Command Uplink MR-243 3.7.1.15.1.12.3 Low Rate Command Uplink MR-242 3.7.1.15.1.12.2 Command Uplink Frequency OBS-124 3.2.1.6.1.1 Communication
MR-78 3.2.1.10 Continuous Two-way Communication	MR-395 3.7.1.15.1.2 Continuous Two-Way Communication	MR-233 3.7.1.15.1.5 Low Rate Commanding OBS-1745 3.2.1.6.1.3 Continuous Two-way Communication
MR-405 3.2.1.11 Launch Phase Communications	MR-407 3.7.1.15.1.3 Launch Phase Communications	
MR-82 3.2.2.1 Deep Space Network	MR-408 3.7.1.15.1.4 Deep Space Network Compatibility	OBS-125 3.2.1.6.2 Deep Space Network Compatibility
MR-395 3.7.1.15.1.2 Continuous Two-Way	MR-233 3.7.1.15.1.5 Low Rate Commanding	OBS-1762 3.2.1.6.9.1.1 Low Rate Commanding

Parent Requirement	Requirement	Child Requirement
Communication		FG-1901 3.1.3.3.4 Command Rates
MR-80 3.2.1.13 Telemetry Bit Error Rate MR-79 3.2.1.12 Command Bit Error Rate	MR-235 3.7.1.15.1.6 Link Margins	GS-083 3.2.10.5 Link Margins OBS-127 3.2.1.6.4 Link Margins FG-91 3.1.1 Link Margin FG-828 3.1.6.1 Ground Station Receiver Implementation LossFG-2287 3.1.6.2 S-Band Downlink Implementation Loss
MR-50 3.2.1.4 Recorded Data Efficiency	MR-236 3.7.1.15.1.7 Downlink of Uncompressed Recorded Engineering Data	MR-130 3.7.1.11.3.1 Storage Capacity OBS-1748 3.2.1.6.5.2 Uncompressed Recoreded Engineering Data Volume FG-1920 3.3.1.1.1.2 Recorded Engineering Telemetry Volume
MR-50 3.2.1.4 Recorded Data Efficiency	MR-237 3.7.1.15.1.8 Stored Data Downlink	GS-069 3.2.10.7.1 Stored Data Downlink OBS-1749 3.2.1.6.7.2 Stored Data Downlink FG-820 3.2.1 Downlink Data Transfer Protocols FG-1330 3.2.1.1.1 Telemetry Packet Definition FG-1331 3.2.1.1.3 Multiplexing Protocol Data Unit Definition FG-1332 3.2.1.1.4 Virtual Channel Data Unit Definition FG-1367 3.2.1.1.2 Telemetry Fill Packet Definition FG-1387 3.2.1.1.4.1 VCDU Version Number FG-1388 3.2.1.1.4.2 Spacecraft ID FG-1389 3.2.1.1.4.3 Telemetry Virtual Channel ID FG-1390 3.2.1.1.4.5 VCDU Counter FG-1391 3.2.1.1.4.7 VCDU Replay Flag FG-1392 3.2.1.1.4.8 VCDU Spare Bits FG-1393 3.2.1.1.4.11 VCDU Operational Control Field for VCID 0 FG-1399 3.2.1.1.4.12 VCDU Operational Control Field for Other

Parent Requirement	Requirement	Child Requirement
		VCIDs FG-1400 3.2.1.1.1.1 Telemetry Packet Version Number FG-1401 3.2.1.1.1.2 Telemetry Packet Type Code FG-1402 3.2.1.1.1.3 Telemetry Packet Secondary Header Flag FG-1403 3.2.1.1.1.4 Telemetry Packet Application Process ID FG-1404 3.2.1.1.1.5 Telemetry Packet Sequence Flags FG-1405 3.2.1.1.1.6 Telemetry Packet Sequence Count FG-1406 3.2.1.1.1.7 Telemetry Packet Data Length FG-1407 3.2.1.1.1.8 Telemetry Packet Secondary Header FG-1408 3.2.1.1.1.9 Telemetry Packet User Data FG-1460 3.2.1.1.4.4 Fill VCDU Virtual Channel ID FG-1461 3.2.1.1.4.9 VCDU Data Unit Zone FG-1462 3.2.1.1.4.10 Fill VCDU Data Unit Zone FG-1505 3.2.3.3.1 CFDP PDU Version FG-1507 3.2.3.3.2 CFDP PDU Type FG-1508 3.2.3.3.3 CFDP PDU Transmission Direction FG-1509 3.2.3.3.4 CFDP PDU Transmission Mode FG-1510 3.2.3.3.5 CFDP PDU CRC Flag FG-1511 3.2.3.3.6 CFDP PDU Reserved Fields FG-1513 3.2.3.3.8 CFDP PDU Length of Entity IDs FG-1514 3.2.3.3.9 CFDP PDU Transaction Sequence Number Length FG-1515 3.2.3.3.10 CFDP PDU Source and Destination Entity IDs

Parent Requirement	Requirement	Child Requirement
		FG-1516 3.2.3.3.11 CFDP PDU Transaction Sequence Number FG-1518 3.2.3.3.12 CFDP PDU Data Field FG-1780 3.2.1.1.4.13 VCDU Operational Control Field for Fill VCDUs FG-1781 3.2.1.1.4.6 Fill VCDU Counter FG-1956 3.2.3.4.1 File Load PDU Encapsulation FG-1958 3.2.3.4.2 Recorded Data PDU Encapsulation FG-1959 3.2.3.1 CFDP Entities FG-1968 3.2.1.2.4 File Dump Data Downlink Protocol FG-1969 3.2.1.2.4.1 File Dump Data CFDP Class of Service FG-1970 3.2.1.2.4.2 File Dump Data PDU Encapsulation FG-1971 3.2.1.2.5 Memory Dump Data FG-1997 3.2.3.2 CFDP Utilization FG-2035 3.3.5.1.1 Recorded Data Downlink Initiation FG-2043 3.3.5.1.5 Halt Recorded Data Playback FG-2061 3.3.2.1 Dump Directory FG-2062 3.3.2.2 Dump File FG-2063 3.3.2.3 Delete File FG-2064 3.3.2.4 Load File FG-2101 3.2.3.4.3 File Dump PDU Encapsulation FG-2143 3.2.1.2.1 Recorded Telemetry/Data CFDP Class of Service FG-2144 3.2.1.2.2 Recorded Telemetry/Data PDU Encapsulation FG-2145 3.2.1.2.3 Real-Time Telemetry/Data Downlink Protocol FG-2178 3.2.3.4.4 Number of PDUs per CCSDS Packet FG-2179 3.2.3.4.5.1 Packet Data Field

Parent Requirement	**Requirement**	**Child Requirement**
		Fill for Short file load and dump PDUs FG-2182 3.2.1.1.4.14 Real-Time Fixed Length Telemetry Packets FG-2195 3.2.1.1.4.11.1 Command Link Control Word Definition FG-2233 3.2.4.1 SSR Science Data Format FG-2238 3.2.4.2 SSR Engineering and Critical Data Format FG-2243 3.2.4.3 SSR Playback Packet APID FG-2264 3.3.5.1.2 Complete File Downlink FG-2265 3.3.5.1.3 Continuous File Downlink FG-2266 3.3.5.1.4 Partial File Downlink FG-2290 3.3.1.2.2 Maximum Size Playback Telemetry Packet
MR-76 3.2.1.8 Downlink of Compressed Science Data Volume	MR-409 3.7.1.15.1.9 Downlink of Compressed Science Data Volume	
MR-49 3.2.1.3 Real-time Data Efficiency	MR-238 3.7.1.15.1.10 Real-Time Data Downlink	GS-070 3.2.10.7.2 Real-Time Data Downlink OBS-1697 3.2.1.6.7.1 Real-Time Data Downlink FG-820 3.2.1 Downlink Data Transfer Protocols FG-1307 3.2.2.3 FARM Control Command Transfer Protocol FG-1330 3.2.1.1.1 Telemetry Packet Definition FG-1331 3.2.1.1.3 Multiplexing Protocol Data Unit Definition FG-1332 3.2.1.1.4 Virtual Channel Data Unit Definition FG-1367 3.2.1.1.2 Telemetry Fill Packet Definition FG-1387 3.2.1.1.4.1 VCDU Version Number

Parent Requirement	Requirement	Child Requirement
		FG-1388 3.2.1.1.4.2 Spacecraft ID FG-1389 3.2.1.1.4.3 Telemetry Virtual Channel ID FG-1390 3.2.1.1.4.5 VCDU Counter FG-1391 3.2.1.1.4.7 VCDU Replay Flag FG-1392 3.2.1.1.4.8 VCDU Spare Bits FG-1393 3.2.1.1.4.11 VCDU Operational Control Field for VCID 0 FG-1399 3.2.1.1.4.12 VCDU Operational Control Field for Other VCIDs FG-1400 3.2.1.1.1.1 Telemetry Packet Version Number FG-1401 3.2.1.1.1.2 Telemetry Packet Type Code FG-1402 3.2.1.1.1.3 Telemetry Packet Secondary Header Flag FG-1403 3.2.1.1.1.4 Telemetry Packet Application Process ID FG-1404 3.2.1.1.1.5 Telemetry Packet Sequence Flags FG-1405 3.2.1.1.1.6 Telemetry Packet Sequence Count FG-1406 3.2.1.1.1.7 Telemetry Packet Data Length FG-1407 3.2.1.1.1.8 Telemetry Packet Secondary Header FG-1408 3.2.1.1.1.9 Telemetry Packet User Data FG-1460 3.2.1.1.4.4 Fill VCDU Virtual Channel ID FG-1461 3.2.1.1.4.9 VCDU Data Unit Zone FG-1462 3.2.1.1.4.10 Fill VCDU Data Unit Zone FG-1505 3.2.3.3.1 CFDP PDU Version FG-1507 3.2.3.3.2 CFDP PDU Type FG-1508 3.2.3.3.3 CFDP PDU Transmission Direction FG-1509 3.2.3.3.4 CFDP PDU

Parent Requirement	Requirement	Child Requirement
		Transmission Mode FG-1510 3.2.3.3.5 CFDP PDU CRC Flag FG-1511 3.2.3.3.6 CFDP PDU Reserved Fields FG-1513 3.2.3.3.8 CFDP PDU Length of Entity IDs FG-1514 3.2.3.3.9 CFDP PDU Transaction Sequence Number Length FG-1515 3.2.3.3.10 CFDP PDU Source and Destination Entity IDs FG-1516 3.2.3.3.11 CFDP PDU Transaction Sequence Number FG-1518 3.2.3.3.12 CFDP PDU Data Field FG-1780 3.2.1.1.4.13 VCDU Operational Control Field for Fill VCDUs FG-1781 3.2.1.1.4.6 Fill VCDU Counter FG-1930 3.4.3 Data for Orbit Determination FG-1956 3.2.3.4.1 File Load PDU Encapsulation FG-1958 3.2.3.4.2 Recorded Data PDU Encapsulation FG-1959 3.2.3.1 CFDP Entities FG-1997 3.2.3.2 CFDP Utilization FG-2101 3.2.3.4.3 File Dump PDU Encapsulation FG-2178 3.2.3.4.4 Number of PDUs per CCSDS Packet FG-2179 3.2.3.4.5.1 Packet Data Field Fill for Short file load and dump PDUs FG-2182 3.2.1.1.4.14 Real-Time Fixed Length Telemetry Packets FG-2195 3.2.1.1.4.11.1 Command Link Control Word Definition
MR-41 3.2.1.1.2 Operational Orbit	MR-239 3.7.1.15.1.11 Ranging	GS-077 3.2.10.7.6 Ranging OBS-1746 3.2.1.6.8.4 Ranging

Parent Requirement	Requirement	Child Requirement
		FG-966 3.4.1 Observatory Ranging FG-973 3.4.1.2 Ranging Accuracy FG-974 3.4.1.3 Ground Station Locations for Ranging FG-994 3.4.1.4 Normal Operations Ranging FG-996 3.4.1.4.1 Number of Ranging Contacts Per Period FG-997 3.4.1.4.2 Interval Between Ranging Contacts During Period FG-1739 3.4.1.5 Post-Separation Ranging FG-1904 3.1.4 Ranging FG-1921 3.4.1.1.1 Range Measurement FG-1923 3.4.1.1.2 Range Rate Measurement FG-1933 3.4.1.4.3 Duration of Ranging Contact FG-2285 3.1.4.1 Ranging Modulation Index
MR-79 3.2.1.12 Command Bit Error Rate	MR-241 3.7.1.15.1.12.1 Command Uplink	GS-063 3.2.10.6.1 Command Uplink OBS-1714 3.2.1.6.7.3 Command Uplink FG-161 3.2.2 Command Transfer Protocols FG-1307 3.2.2.3 FARM Control Command Transfer Protocol FG-1319 3.1.3.3 S-Band Command Link FG-1410 3.2.2.1.1 Command Packet Definition FG-1434 3.2.2.1.1.1 Command Packet Version Number FG-1435 3.2.2.1.1.2 Command Packet Type FG-1436 3.2.2.1.1.3 Command Packet Secondary Header Flag FG-1437 3.2.2.1.1.4 Command Packet Application Process ID FG-1438 3.2.2.1.1.5 Command Packet

Parent Requirement	Requirement	Child Requirement
		Sequence Flags FG-1439 3.2.2.1.1.7 Command Packet Source Sequence Count FG-1440 3.2.2.1.1.8 Command Packet Data Length FG-1443 3.2.2.1.1.11 Command Packet User Data FG-1505 3.2.3.3.1 CFDP PDU Version FG-1507 3.2.3.3.2 CFDP PDU Type FG-1508 3.2.3.3.3 CFDP PDU Transmission Direction FG-1509 3.2.3.3.4 CFDP PDU Transmission Mode FG-1510 3.2.3.3.5 CFDP PDU CRC Flag FG-1511 3.2.3.3.6 CFDP PDU Reserved Fields FG-1513 3.2.3.3.8 CFDP PDU Length of Entity IDs FG-1514 3.2.3.3.9 CFDP PDU Transaction Sequence Number Length FG-1515 3.2.3.3.10 CFDP PDU Source and Destination Entity IDs FG-1516 3.2.3.3.11 CFDP PDU Transaction Sequence Number FG-1518 3.2.3.3.12 CFDP PDU Data Field FG-1664 3.2.2.1.1.6 Number of Commands Per Packet FG-1665 3.2.2.1.1.9 Command Packet Secondary Header "Not Used" Field FG-1667 3.2.2.1.2 Command Transfer Frame Definition FG-1668 3.2.2.1.2.1 Transfer Frame Version Number FG-1672 3.2.2.1.2.2 Transfer Frame Bypass Flag FG-1673 3.2.2.1.2.3 Transfer Frame Control Command Flag FG-1674 3.2.2.1.2.5 Transfer Frame Spare Bit Field

Parent Requirement	Requirement	Child Requirement
		FG-1675 3.2.2.1.2.6 Transfer Frame Spacecraft ID FG-1676 3.2.2.1.2.7 Transfer Frame Virtual Channel ID FG-1677 3.2.2.1.2.9 Transfer Frame Length FG-1678 3.2.2.1.2.10 Transfer Frame Sequence Number for Type A Frames FG-1679 3.2.2.1.2.12 Transfer Frame Data Field FG-1680 3.2.2.1.2.13 Transfer Frame Error Control FG-1681 3.2.2.1.2.4 Transfer Frame Bypass and Control Command Flag Combinations FG-1729 3.2.2.1.2.11 Transfer Frame Sequence Number for Type B Frames FG-1730 3.2.2.1.3 Command Link Transmission Unit Definition FG-1731 3.2.2.1.3.1 CLTU Format FG-1732 3.2.2.1.3.2 Codeblock Format FG-1733 3.2.2.1.3.3 Codeblock Parity Check FG-1734 3.2.2.1.3.4 Codeblock Data Field Fill Bits FG-1736 3.2.2.1.3.5 Codeblock Data Randomization FG-1799 3.2.2.1.2.8 Virtual Channel Command Link Control Word FG-1899 3.1.3.3.2 Command Subcarrier Modulation FG-1900 3.1.3.3.3 Occupied Bandwidth FG-1956 3.2.3.4.1 File Load PDU Encapsulation FG-1958 3.2.3.4.2 Recorded Data PDU Encapsulation FG-1959 3.2.3.1 CFDP Entities FG-1980 3.2.2.2.1 File Load Command Protocol FG-1981 3.2.2.2.1.1 File Load CFDP

Parent Requirement	Requirement	Child Requirement
		Class of Service FG-1982 3.2.2.2.1.2 File Load CFDP PDU Encapsulation FG-1983 3.2.2.2.1.3 File Load Command Packet Transport Protocol FG-1984 3.2.2.2.2 Memory Load and General Function Command Protocol FG-1985 3.2.2.2.3 Bypass Command Protocol FG-1986 3.2.2.2.4 CFDP Transaction Message Encapsulation and Transfer Protocol FG-1997 3.2.3.2 CFDP Utilization FG-2061 3.3.2.1 Dump Directory FG-2062 3.3.2.2 Dump File FG-2063 3.3.2.3 Delete File FG-2064 3.3.2.4 Load File FG-2101 3.2.3.4.3 File Dump PDU Encapsulation FG-2178 3.2.3.4.4 Number of PDUs per CCSDS Packet FG-2179 3.2.3.4.5.1 Packet Data Field Fill for Short file load and dump PDUs FG-2182 3.2.1.1.4.14 Real-Time Fixed Length Telemetry Packets FG-2206 3.2.2.1.2.13.1 Method For Checksum Calculation FG-2207 3.2.2.1.3.6 Number Of Transfer Frames Per CLTU FG-2208 3.2.2.2.4.1 File Directive PDU FG-2214 3.2.2.2.4.2 Meta Data PDU FG-2215 3.2.2.2.4.3 ACK PDU FG-2216 3.2.2.2.4.4 NAK PDU FG-2217 3.2.2.2.4.5 EOF PDU FG-2218 3.2.2.2.4.6 Finished PDU FG-2220 3.2.2.2.5.1 Command Authentication FG-2221 3.2.2.2.5.2 Command Rejection FG-2223 3.2.2.2.5.4 Authentication

Parent Requirement	Requirement	Child Requirement
		Timers FG-2224 3.2.2.2.5.5 Authentication Counters FG-2225 3.2.2.2.5.6 Disable/Enable Authentication Command FG-2226 3.2.2.2.5.7 Loss of Authenticated Link FG-2227 3.2.2.2.5.8 Reauthenticate Flag FG-2228 3.2.2.2.5.9 Authentication Default Configuration FG-2229 3.2.2.2.5.10 Enable Authentication Via Hardware FG-2230 3.2.2.2.5.3.1 Authentication Password FG-2231 3.2.2.2.5.3.2 Authentication Password Change Command FG-2288 3.2.2.2.6 Commandable Inhibits
MR-232 3.7.1.15.1.1 Communication Operations	MR-242 3.7.1.15.1.12.2 Command Uplink Frequency	GS-064 3.2.10.6.2 Command Uplink Frequency OBS-1752 3.2.1.6.8.1 Command Uplink Frequency FG-1898 3.1.3.3.1 Frequency Band
MR-232 3.7.1.15.1.1 Communication Operations	MR-243 3.7.1.15.1.12.3 Low Rate Command Uplink	GS-065 3.2.10.6.3 Low Rate Command Uplink OBS-1763 3.2.1.6.9.1.2 Low Rate Command Uplink FG-1901 3.1.3.3.4 Command Rates
MR-232 3.7.1.15.1.1 Communication Operations	MR-244 3.7.1.15.1.12.4 Medium Rate Command Uplink	GS-066 3.2.10.6.4 Medium Rate Command Uplink OBS-1764 3.2.1.6.9.1.3 Medium Rate Command Uplink FG-1901 3.1.3.3.4 Command Rates
MR-232 3.7.1.15.1.1 Communication Operations	MR-245 3.7.1.15.1.12.5 High Rate Command Uplink	
MR-80 3.2.1.13 Telemetry Bit Error Rate	MR-248 3.7.1.15.1.13.1 Downlink Data Encoding	GS-071 3.2.10.7.3 Downlink Data Encoding OBS-1750 3.2.1.6.7.4 Downlink Data Encoding

Parent Requirement	Requirement	Child Requirement
		FG-1333 3.2.1.1.5 Encoded Virtual Channel Data Unit Definition FG-1411 3.2.1.1.7 Channel Access Data Unit Definition FG-1738 3.2.1.1.6 Reed-Solomon Coding Specification FG-1778 3.2.1.1.9 Fill CADU Transmission FG-1779 3.2.1.1.10 Fill CADU Definition FG-1886 3.1.2.5 Ka-Band Downlink Data Encoding FG-1913 3.1.3.2.7 Low Rate Telemetry Downlink Encoding
MR-80 3.2.1.13 Telemetry Bit Error Rate	MR-249 3.7.1.15.1.13.2 Pseudo-Randomization of Data	GS-072 3.2.10.7.4 Pseudo-Randomization of Data OBS-1751 3.2.1.6.7.5 Pseudo-Randomization of Data FG-1737 3.2.1.1.8 Telemetry Randomization
MR-77 3.2.1.9 Normal Operations	MR-250 3.7.1.15.1.13.3 Low Rate Downlink	MR-260 3.7.1.15.1.14.2 Telemetry GS-073 3.2.10.7.5 Low Rate Downlink OBS-1753 3.2.1.6.8.2 Low Rate Downlink FG-1177 3.1.3.1 S-Band Omni Antenna Coverage FG-1892 3.1.3.2.1 Frequency Band FG-1893 3.1.3.2.4 Telemetry Subcarrier Modulation FG-1894 3.1.3.2.5 Telemetry Occupied Bandwidth FG-1918 3.3.1.1.2 S-Band Downlink Usage FG-2183 3.1.3.2.4.1 Telemetry Modulation Index FG-2202 3.1.3.2.10 S-band Power Flux Density FG-2203 3.1.3.2.11 S-band Out-of-band Emissions FG-2284 3.1.3.5 S-band Spacecraft

Parent Requirement	Requirement	Child Requirement
		Antenna Characteristics
MR-232 3.7.1.15.1.1 Communication Operations	MR-256 3.7.1.15.1.13.4 High Rate Downlink	MR-257 3.7.1.15.1.10.5 High Rate Downlink Data Rates GS-078 3.2.10.7.7 High Rate Downlink OBS-1754 3.2.1.6.8.3 High Rate Downlink FG-1882 3.1.2.1 Frequency Band FG-1883 3.1.2.2 Occupied Bandwidth FG-1884 3.1.2.3 Ka-Band Modulation FG-1888 3.1.2.7 Ka-Band Link Weather Availability FG-1891 3.1.2.8 Ka-Band Power Flux Density FG-2181 3.1.2.9 Out of Band Emissions FG-2278 3.1.2.3.1 Ka-Band Link CADU Splitting FG-2282 3.1.2.10 Ka-band Spacecraft Antenna Characteristics
MR-256 3.7.1.15.1.10.4 High Rate Downlink	MR-257 3.7.1.15.1.13.5 High Rate Downlink Data Rates	GS-079 3.2.10.7.8 High Rate Downlink Data Rates OBS-1770 3.2.1.6.9.2 High Rate Downlink Data Rates FG-1885 3.1.2.4 Ka-Band Data Rates
MR-232 3.7.1.15.1.1 Communication Operations	MR-259 3.7.1.15.1.14.1 Commanding	OBS-1756 3.2.1.6.10.1 Commanding FG-1901 3.1.3.3.4 Command rates
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