Mission Requirements Document (MRD) Hierarchy

1 Science Requirements

1.1 Science Observations
1.2 Data Capture & Completeness
1.3 Angular Resolution & Coverage
1.5 Precision, Acc, & Dyn Range
1.6 Cadence

2 Mission Implementation

2.1 Orbit
2.2 Mission Life
2.3 Environment
2.4 Launch Vehicle (LV)
2.5 Mission Implem/ Ops Concept
2.6 Standard Spacecraft Services
2.7 Development Approach

3 Instrument Requirements

3.1 EVE
3.1.1 Alignment, Jitter & Stability
3.1.2 Spectral Resolution
3.1.3 Timing
3.1.4 Data Completeness
3.1.5 Interface Requirements
3.2 HMI
3.2.1 Alignment & Jitter
3.2.2 Angular Resolution
3.2.3 Timing
3.2.4 Data Completeness
3.2.5 Interface Requirements
3.3 SHARPP
3.3.1 Alignment & Jitter
3.3.2 Angular Resolution
3.3.3 Timing
3.3.4 Data Completeness
3.3.5 Interface Requirements
3.3.6 Dynamic Range

4 Spacecraft Requirements

4.1 Structural /Thermal
4.1.1 Launch Vehicle Accommodation
4.1.2 S/C & Instr Accom.
4.1.3 Thermal Monitoring and Control
4.1.4 Instrument Optical Bench
4.2 Attitude Control & Determination
4.2.1 Acquisition
4.2.2 Pointing Knowledge
4.2.3 Attitude Control and Stability
4.2.4 Propulsion & Delta-V
4.2.5 Momentum Management
4.2.6 Safehold
4.3 Power
4.3.1 Power Generation
4.3.2 Power Storage
4.3.3 Power Distribution
4.3.4 Load Shedding
4.3.5 Constraints
4.4 Comm & Data System
4.4.1 S-Band Communications
4.4.2 Ka-Band Communications
4.4.3 Data System Functions
4.5 HGA Assembly
4.5.1 Operation, Pointing and Stability
4.6 Deploy Actuation and Verif
4.6.1 Solar Array Deploy and Verif
4.6.2 HGA Deployment and Verification

5 Ground Segment Requirements

5.1 Integration and Test (I&T)
5.1.1 High Rate Science GSE
5.1.2 Low Rate GSE
5.2 Ground Station Implementation
5.2.1 Dedicated Site Requirements
5.2.2 Ancillary Site Requirements
5.2.3 Commanding
5.2.4 Housekeeping Telemetry
5.2.5 Tracking
5.2.6 Science Telemetry
5.3 Mission Operations Center (MOC)
5.3.1 Cmd and Tlm Functions
5.3.2 Data Products
5.4 Science Operations Center (SOC)
5.4.1 Ops
5.4.2 Archive
5.4.3 Data Products

APS- Antenna Pointing System
C&DH- Command & Data Handling Subsystem
CONTAM- Contamination Subsystem
DEPLOY- Deployment Subsystem
ELEC- Electrical Systems
FLT DYN- Flight Dynamics Subsystem
FSW- Flight Software Subsystem
GN&C- Guidance, Navigation and Control Subsystem
GND- Ground Segment
GSE- Ground Support Equipment Subsystem
INSTR- Instruments (EVE, HMI, SHARPP)
LV- Launch Vehicle
MATL - Materials and Process Subsystem
MECH- Mechanical Subsystem
PARTS- Parts Subsystem
PROP- Propulsion Subsystem
PWR- Power Subsystem
RAD- Radiation Effects Subsystem
RF- RF Communications Subsystem
THERM- Thermal Subsystem

Observatory = Combination of Spacecraft flight segment and Instrument flight segments

Instruments = EVE, HMI, & SHARPP Flight segments

SOC = Science Operations Center

Ground System = Command and control facility and equipment located in the Mission Operations Center (MOC)

Ground Station = Remotely located antenna site and data distribution facility

Ground Segment = All ground elements, including ground system, Instrument SOCs, SDO ground station, and any ancillary ground stations

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
1		**Science Requirements**										
1.1		**Science Observations**	**The science mission shall perform solar observations sufficient to characterize solar activity as the sun exits from a period of solar minimum and progresses to a period of solar maximum**	**N/A**	**N/A**	**N/A**	**N/A**					
1.1.1				The SDO Observatory will launch during or shortly after solar minimum (June 2007 to August 2008 (TBR)) in order to permit observations as the solar cycle progresses towards solar maximum	Defines launch requirement within a range that allows initial observations at end of solar minimum	Project	Lev.1 [Science Objectives, Mission Timeline Success Criteria in 4.1.1]					
1.1.2				Science observations shall cover 5 years of the progression from solar minimum to solar maximum to meet full mission success science requirements	Comments: Minimum success will be achieved with a series of observations spanning both minimum and maximum conditions, ideally met with a 3-year observation period (c.f. : Level 1 Science Requirements Document for full details).	ALL	Lev.1 [Science Objectives, Mission Timeline Success Criteria in 4.1.1]					
1.2		**Data Capture & Completeness**	**The end-to-end system of the SDO Instrument, Spacecraft, and Ground System shall obtain and deliver solar observations to the Investigator's SOCs of sufficient quality to achieve the mission science objectives.**	**N/A**	**N/A**	**N/A**	**N/A**					
1.2.1				The end-to-end HMI Data Capture budget requires 95% of all possible science data over the SDO mission, including delivery of these data to the SOCs. The EVE and SHARPP data capture budgets require 90% of all possible science data.	For minimum mission success, the Observatory shall return 80% of SHARPP and EVE data, while a completeness of up to 95% (depending on the campaign) is specified in the HMI Science Observation Requirements table in the Level 1 Science Requirements Document. Note that HMI is the driver of this requirement as well as the completeness requirement. Requirement addressed through the use of a configured data capture budget. Is this requirement quantifiable?	INSTR, C&DH, GN&C, APS, RF, GND	Lev.1 [Science Meas. 1 in 4.1.1]					
1.2.2				The combined HMI Instrument, Spacecraft, and Ground System shall provide an end-to-end data completeness of 99.99% over periods of minutes to hours.The requirement for EVE is 99.6% and SHARPP is 99.9% (TBR).	The HMI observable construction requires minimizing data loss in order to calculate Dopplergrams and magnetograms from a series of filtergrams. The completeness value for EVE and SHARPP will be reviewed to ensure that this value does not unnecessarily drive BER for the instruments.	INSTR, C&DH, RF, GND	Lev.1 [Science Meas. 1 in 4.1.1]					
1.2.3				Individual solar observations shall consist of a minimum of 10 minutes of continuous observation.	Requirement addressed minimum HMI Dopplergram observation duration. Planned gaps should be kept short and as non-periodic as possible.	INSTR, C&DH, APS, RF, GND	Lev.1 [Science Meas. 1 in 4.1.1]					
1.2.4				Deleted								
1.2.5				Deleted								
1.3		**Angular Resolution & Coverage**	**The Instruments shall provide adequate angular resolution and image field of view to meet the Level 1 Science Requirements**	**N/A**	**N/A**	**N/A**	**N/A**					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
1.3.1				Dopplergrams shall cover the full disk with a sampling of about 0.5 arcsec per pixel, and image quality and stability that enable a resolution of <1.5 arcsec.	Drives high frequency jitter and instrument resolution. Full disk image defines FOV, absolute pointing, and data rate. Using the Rayleigh criterion for diffraction limited resolution, 0.5 arcsec pixels would give 1.2 arcsec angular resolution that would then increase for non perfect optics, pointing, photon statistics, charge spreading, etc.	HMI	Lev.1 [Science Meas. 1 in 4.1.1]					
1.3.2				Longitudinal and vector magnetograms shall cover the full disk with a sampling of about 0.5 arcsec per pixel, and image quality and stability that enable a resolution of <1.5 arcsec.	Drives high frequency jitter and instrument resolution. Full disk image defines FOV, absolute pointing, and data rate. Using the Rayleigh criterion for diffraction limited resolution, 0.5 arcsec pixels would give 1.2 arcsec angular resolution that would then increase for non perfect optics, pointing, photon statistics, charge spreading, etc.	HMI	Lev.1 [Science Meas. 2 in 4.1.1]					
1.3.3				Magritte atmospheric images shall cover the sun out to 1.4 solar radii with a sampling of 0.66 arcseconds per pixel	Drives jitter but not pointing. 1.32 arcsecond resolution stems from the requirement that a resolved feature should be less than 2 pixels wide (0.66 arcseconds/pixel).	SHARPP	Lev.1 [Science Meas. 4 in 4.1.1]					
1.3.3.1				Spectre atmospheric images shall cover the sun out to 1.2 solar radii with a sampling of 0.6 arcseconds per pixel.		SHARPP	Lev.1 [Science Meas. 6 in 4.1.1]					
1.3.4				Coronographic images shall cover the sun from 2 to 15 solar radii with a sampling of 15 arcseconds per pixel	Drives pointing. 30 arcsecond resolution stems from the requirement that a resolved feature should be less than 2	SHARPP	Lev.1 [Science Meas. 6 in 4.1.1]					
1.3.5				Spectral Irradiance measurements must consist of integrated disk measurements over a field of view extending to 1.8 solar radii from the center of the solar disk.	Ensures overlap of EVE and SHARPP measurements.	EVE	Lev.1 [Science Meas. 6 in 4.1.1]					
1.4		**Spectral Resolution & Wavelength Range**	**The Instruments shall provide adequate spectral resolution and range to meet Level 1 spectral irradiance and atmospheric imaging measurements**	**N/A**	**N/A**	**N/A**	**N/A**					
1.4.1				Solar Spectral irradiance measurements shall be performed to cover in the 0.1 to 105 nm range	For minimum mission success, 6 or more emissions to specify the chromosphere, TR, and corona, plus the He II 30.4 nm emission.	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
1.4.2				Spectral resolution of 0.1 nm for a minimum of 18 emission lines shall be achieved	For minimum mission success, .2 nm for 6 emissions.	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
1.4.3				Spectral resolution of 5 nm for other emission lines shall be achieved	No corresponding measurements for minimum mission.	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
1.4.4				Atmospheric images shall cover the temperature range spanning 20,000 to 3,000,000 K with 7 wavebands	AIA requirement: 7 telescopes for 7 different wavebands	SHARPP	Lev.1 [Science Meas. 4 in 4.1.1]					
1.5		**Precision, Accuracy, & Dynamic Range**	**The Instruments shall provide adequate measurement accuracy over the require measurement range to meet the Level 1 Requirements**	**N/A**	**N/A**	**N/A**	**N/A**					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
1.5.1				The Dopplergram velocity dynamic range shall be <25 m/sec over a period of 50 sec.	This flows down to a requirement that images be co-aligned on an HMI sensor to 0.1 arcsec (3-sigma) over the 50-second interval needed for one set of images to limit noise from intensity gradients and image shifts. Note that 15 Km/sec Doppler shift only possible in orbits where Doppler shift is small between observations, such as GEO or L1 orbits.	HMI	Lev.1 [Science Meas. 1 in 4.1.1]					
1.5.2				Longitudinal magnetograms shall have a zero point error of <0.3 Gauss.	Do we need a definition of zero point error?	HMI	Lev.1 [Science Meas. 2 in 4.1.1]					
1.5.3				Longitudinal magnetograms shall have a noise level of < 5 Gauss over a period of 10 minutes.	This flows down to a requirement that images be co-aligned on an HMI sensor to 0.1 arcsec (3-sigma) over the 50-second interval needed for one set of images to limit noise from intensity gradients and image shifts. Note that 15 Km/sec Doppler shift only possible in orbits where Doppler shift is small between observations, such as GEO or L1 orbits.	HMI	Lev.1 [Science Meas. 2 in 4.1.1]					
1.5.4				Longitudinal and vector magnetograms shall have a dynamic measurement range of +-3 kGauss		HMI	Lev.1 [Science Meas. 2, 3 in 4.1.1]					
1.5.5				The polarimetric precision in Q, U, and V should be better than 0.3% in 10 minutes.	Q, U, and V are the basic polarimetry measurements from which the vector magnetic field is derived. The noise level and systematic errors of vector magnetic field measurements are complicated functions of solar conditions and Q, U, and V. This also flows down to the image stability requirement of 0.1 arcsec (3 sigma).	HMI	Lev.1 [Science Meas. 2 in 4.1.1]					
1.5.6				Calibration of the intensity of the atmospheric images shall be 10%. This absolute calibration is defined to be the daily averaged integrated solar disk intensity.	Minimum mission success shall be 20% (TBR). SHARPP calibration requirements should not exceed those of EVE.	SHARPP	Lev.1 [Science Meas. 4 in 4.1.1]					
1.5.7				Signal to noise of atmospheric images shall be 8 in quiet sun, 20 in active sun	6 in quiet sun, 15 inactive sun for minimum mission success.	SHARPP	Lev.1 [Science Meas. 4 in 4.1.1]					
1.5.8				Coronagraphic images shall have a calibrated intensity precision (absolute accuracy) of 10%	20% for minimum mission success.	SHARPP	Lev.1 [Science Meas. 6 in 4.1.1]					
1.5.9				Spectral irradiance measurements shall have an absolute accuracy of 10% (1sigma) for the daily average in 5 nm intervals and 10% (1sigma) for the brighter emission lines at the measurement cadence of 20 sec or shorter.	20% for minimum mission success.	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
1.5.10				Spectral irradiance measurements shall have a precision of 2% (1 sigma) per year	5% for minimum mission success.	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
1.6		**Cadence**	**The Instruments shall provide data sets with adequate cadence to study solar phenomena on appropriate time scales**	**N/A**	**N/A**	**N/A**	**N/A**					
1.6.1				The dopplergrams shall have an observation cadence of no higher than 50 seconds	Drives instr observation timing, instr processing & data rate	HMI	Lev.1 [Science Meas. 1 in 4.1.1]					
1.6.2				The longitudinal magnetograms shall have an observation cadence of no higher than 50 seconds	Drives instr observation timing, instr processing & data rate	HMI	Lev.1 [Science Meas. 2 in 4.1.1]					
1.6.3				The vector magnetograms shall have an observation cadence of no higher than 5 minutes	Drives instr observation timing, instr processing & data rate	HMI	Lev.1 [Science Meas. 3 in 4.1.1]					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
1.6.4				The atmospheric images shall have an observation cadence of no higher than 10 seconds	20 seconds for minimum success. Drives instr observation timing, instr processing & data rate	SHARPP	Lev.1 [Science Meas. 4 in 4.1.1]					
1.6.5				The coronagraphic images shall have an observation cadence of no higher than 60 seconds	80 seconds for minimum success. Drives instr observation timing, instr processing & data rate	SHARPP	Lev.1 [Science Meas. 6 in 4.1.1]					
1.6.6				The spectral irradiance measurements shall have an observation cadence of no higher than 20 sec or better seconds	60 seconds for minimum success. Drives instr observation timing, instr processing & data rate	EVE	Lev.1 [Science Meas. 5 in 4.1.1]					
2		Mission Implementation										
2.1		**Orbit**	**SDO orbit shall be selected to support the instrument science requirements and overall ops concept**	**N/A**	**N/A**	**N/A**	**N/A**					
2.1.1				Geosynchronous orbit with an initial RAAN of 200 +/- 7.5 degrees longitude	Geo orbit allows continuous ground contact for high rate downlink and introduces an acceptable orbital Doppler shift and orbital period for HMI measurements; RAAN selection minimizes eclipse season impacts to science data collection; also has impacts on antenna FOV and handovers in degraded mode. Tolerance on RAAN defines launch window (each 1 hour widening of window results in 15 deg RAAN shift). Launch window opens at 192.5 degrees	LV, GN&C, PROP, FLT DYN	Lev.1 [Science Meas. 1], 1.2.1 (Data Capture & Comp.), 1.5.1 (Dopplergram accuracy), 1.6 (Cadence)					
2.1.2				The Observatory shall be designed to support operations in an orbit with two yearly eclipse seasons with a maximum duration of 23 days, each with a maximum daily shadow of 72 minutes	Eclipse seasons indicated in AO. Orbit eclipse characteristics derived from RAAN selection	GN&C, FLT, DYN, PROP, MECH, THERM, PWR	Lev.1 [Science Meas.], 1.2.1 (Data Capture & Compl)					
2.1.3				The orbit shall be selected to have an average longitudinal stationkeeping position within a range of 100-110 deg W longitude	Based on gravity well at specified position which minimizes stationkeeping maneuvers	LV, GN&C, FLT, DYN, PROP	Lev.1 [Science Meas.], 1.2.1 (Data Capture & Compl)					
2.1.4				The Observatory shall maintain a stationkeeping position within +/- 0.5 deg of its allocated average longitudinal position	Based typical longitudinal orbit slot for Geo Spacecraft	GN&C, FLT, DYN, PROP, GND	Lev.1 [Science Meas.], 1.2.1 (Data Capture & Compl)					
2.1.5				The mission shall be designed to remain within a maximum orbital eccentricity of 0.005 (TBR) over the course of a 5 year mission	Defines orbit characteristics- does not place prohibitive reqs on orbit; Affects HGA/ground station pointing angle (minimizes antenna pointing angles) & Delta-V stationkeeping budget; Eccentricity provides predictable range for HMI doppler effects; Keeps observatory above outer Van Allen belt	GN&C, FLT, DYN, PROP, GND	Lev.1 [Science Meas.], 1.2.1 (Data Capture & Comp.), 1.5.1 (Dopplergram accuracy)					
2.1.6				The Observatory and mission shall be designed for a maximum orbital inclination of < 30 (TBR) over the 5 year mission life	Initial inclination at launch planned to be 28.7 deg; Affects HGA/ground station pointing angle & Delta-V stationkeeping budget	GN&C, FLT, DYN, PROP, GND	Lev.1 [Science Meas.], 1.2.1 (Data Capture & Comp.)					
2.2		**Mission Life**	**Mission life shall be sufficient to achieve science data collection to meet fundamental science requirements**	**N/A**	**N/A**	**N/A**	**N/A**					
2.2.1				5 Year Mission Life (after reaching on-station GEO orbit and post commissioning activities)	Derived from Level 1 Reqs; Level 1 doc indicates three years as minimum mission life.	ALL	Lev.1 [Science Objectives, Mission Timeline Success Criteria in 4.1.1], 1.1.2 (Science Observ)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.2.2			The SDO Spacecraft shall be designed to be single fault tolerant and still meet minimum mission success criteria or shall employ sufficient testing or analysis to ensure system reliability where fault tolerance and graceful degradation does not exist		Project guidelines direct the design of the most robust and fault tolerant system within the constraints of allocated resources. Requirement reflects accepted design practice commensurate with mission scope; spacecraft will employ the use of redundancy, cross-strapping and spacecraft system design that promotes graceful degradation of the SDO spacecraft functions in the event of an anomaly or failure to allow spacecraft to meet 5 year goal; Anticipate that the redundancy implementation required to meet project-level reliability requirements for a 5 year mission	ALL	1.1.2 (Science Observ), 2.2.1 (Mission Life)					
2.2.3				The Observatory design shall support the inclusion of propellant and OFS gas for a 10 year mission life	Reflects headquarters goal for operation if observatory is functional beyond mission life requirement; subject to project resource constraints	PROP, GN&C, FLT DYN, MECH	Lev.1 [Science Objectives, Mission Timeline Success Criteria in 4.1.1], 1.1.2 (Science Observ)					
2.3		**Environment**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**					
2.3.1		Initial Orbital Insertion Environment	The Observatory shall be able to withstand and operate within the conditions of the initial Geo Transfer Orbit through orbit change to on-station geosynchronous position				2.1 (Orbit)					
2.3.1.1				The Observatory shall be able to survive 10 (TBR) orbits at 185 km perigee altitudes without any degradation to the Observatory or science mission	Addresses need to survive multiple low altitude perigee passes and the resultant effects on the Observatory and spacecraft performance (Atomic oxygen degradation, aeroheating, RW saturation, etc)	CONTAM, GN&C, MATL, RAD, THERM, Electrical subsystems	2.1 (Orbit)					
2.3.1.2				The Observatory shall be able to survive 50 (TBR) orbits through the outer Van Allen Belts without any degradation to the Observatory or science mission	Addresses potential of extended radiation exposure through Van Allen belts during orbit raising from GTO to Geo	RAD, Electrical subsystems, MATL	2.1 (Orbit)					
2.3.2		Radiation Effects & Design	The SDO Observatory shall survive the radiation environment of the mission	N/A	N/A	RAD, INSTR, Electrical subsystems, PARTS, MATL	1.5 (Precision), 2.1.2 (Mission life), 2.1.1 (Orbit)					
2.3.2.1			Parts TID requirements shall be based on the effective shielding provided by the SDO Observatory ray trace and dose/depth curve detailed in the SDO Radiation Environment document (Doc # TBD)		Radiation calculations indicate 400 Krad TID behind 100mils Al for a 5 year mission (includes a 2x margin for uncertainty of model and variability of environment); reduces to 40 Krad over five years for an effective parts shielding of 200 mils Al. SDO ray trace provides specifics of effective shielding provided by Observatory	RAD, INSTR, Electrical subsystems, PARTS, MATL	2.1.1 (Orbit), 2.2.1 (Mission Life)					
2.3.2.2				The parts selected shall be immune to destructive SEEs (part LET > 100MeV {TBR})		RAD, INSTR, Electrical subsystems, PARTS	2.2.1 (Orbit), 2.1.2 (Mission Life)					
2.3.2.3				Parts which demonstrate susceptibility to non-destructive SEE's at an LET lower than 37 MeV (TBR) shall not degrade mission performance. Radiation effects analysis and a criticality assessment should be conducted as part of the assessment of mission performance effects.	SEE susceptible parts may be included if accompanied by design mitigation which eliminates SEE consequences in S/C performance (circuit design, non-critical usage, etc)	RAD, INSTR, Electrical subsystems, PARTS	2.1.1 (Orbit), 2.2.1 (Mission Life)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.3.3		Spacecraft Charging	The SDO Observatory design shall prevent surface and internal charging/discharging effects that damage Observatory components or disrupt Observatory operations	N/A	N/A	N/A	N/A					
2.3.3.1		Surface Charging	The Observatory shall be designed to dissipate collected charge on external surfaces to prevent damaging ESD discharge		Reference NASA technical paper 2361 titled "Design Guidelines for Assessing and Controlling Spacecraft Charging Effects" can be used as a guide for the prevention of spacecraft charging.	RAD, INSTR, ELEC, Electrical subsystems, MECH, DEPLOY, THERM, MATL	2.1.1 (Orbit), 2.1.2 (Mission Life)					
2.3.3.1.1			The Observatory shall have sufficient conductive surface area on the sun-facing side to allow dissipation of collected charge from the entire Observatory		Reflects the effect that surface charge collects on darkened conductive surfaces and dissipates from sun-facing conductive surfaces; requires conductive path between all Observatory surfaces to prevent isolated charge buildup	RAD, INSTR, ELEC, Electrical subsystems, MECH, DEPLOY, THERM, MATL	2.1.1 (Orbit), 2.2.1 (Mission Life)					
2.3.3.1.2				TBD % of all Observatory external surfaces shall be conductive (<= 1E9 Ohms/sq) with no single continuous non-conductive surface area greater than TBD	This requirement addresses surface charge control and provides specfic requirements to 2.3.3.1.2 above. Does not apply to optical apertures and other similar surfaces. Refer to the SDO Electrical Systems Spec (doc # TBD) for specific design implementation guidelines	RAD, INSTR, ELEC, Electrical subsystems, MECH, DEPLOY, THERM, MATL	2.1.1 (Orbit), 2.2.1 (Mission Life)					
2.3.3.2		Internal Charging	No internal discharge shall cause permanent damage to the Observatory circuitry.		NASA HandBook-4002 on Spacecraft Charging can be used as a reference for internal spacecraft charging.	Rad, INSTR, ELEC, Electrical subsystems, MECH, MATL	2.1.1 (Orbit), 2.2.1 (Mission Life)					
2.3.3.2.1			The Observatory shall have sufficient shielding to prevent dielectric charge buildup to prevent ESD discharge effects		This requirement addresses internal charge control. Refer to the SDO Electrical Systems Spec (doc # TBD) for specific design implementation guidelines	RAD, INSTR, ELEC, Electrical subsystems, MECH	2.1.1 (Orbit), 2.2.1 (Mission Life)					
2.3.4		Contamination	N/A	N/A	N/A	N/A	N/A					
2.3.4.1		Flight Configuration/Ops	Contamination of sensitive portions of the Observatory by condensables and particulates shall not prevent the mission from meeting its requirements	N/A	N/A	ALL	Lev. 1 [Precision (Science Meas. 1-6)], 2.2.1 (Mission Life)					
2.3.4.1.1			Acceptable levels of contamination shall be maintained on the Observatory per the SDO Contamination Control Plan (Doc # TBD)			ALL	Lev. 1 [Precision (Science Meas. 1-6)], 2.2.1 (Mission Life)					
2.3.4.2		I&T Activities	Contamination from I&T activities shall not prevent the mission from meeting its requirements	N/A	N/A	ALL	Lev. 1 [Precision (Science Meas. 1-6)]					
2.3.4.2.1				Class 10,000 facilities are required for the instrument and propulsion integration and test phases	Requirement based on the proposal information indicating that higher cleanliness standards are required during instrument-level assembly and testing	ALL	Lev. 1 [Precision (Science Meas. 1-6)]					
2.3.4.2.2				Class 10,000 facilities are required for the Observatory integration and test phases		ALL	Lev. 1 [Precision (Science Meas. 1-6)]					
2.3.4.2.3			The Observatory shall be designed to incorporate and allow the use of Instrument dry purge lines throughout the Observatory integration and test phases		Requirement based on instrument cleanliness requirements and specific requirements stated in instrument proposals	CONTAM, MECH, GSE, INSTR	Lev. 1 [Precision (Science Meas. 1-6)]					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.3.5		Magnetics	Observatory residual and induced magnetic fields and the natural orbital environmental magnetic field shall not disrupt Observatory operations or corrupt mission science	N/A	N/A	CONTAM, INSTR, ELEC, Electrical subsystems, MATL	Lev. 1 [Precision (Science Meas. 1-6)]					
2.3.5.1				The EVE OFS instrument shall be able to meet instrument operational and science requirements in the presence of a magnetic field no greater than TBD (300 nTesla??) at the EVE instrument location	Magnetic environment consists of natural orbital magnetic field at GEO (~ 170 nTesla) and EVE team needs to do a reassessment of magnetic susceptibility and possible shielding. Variations in magnetic field through GEO orbit are also a significant potential issue for EVE measurements. EVE is sensitive to magnetic fields - affects EVE spectral resolution measurements at longest wavelength photons. May need to do an on-orbit magnetic shield assessment.	CONTAM, INSTR, ELEC, Electrical subsystems, MATL	Lev. 1 [Precision (Science Meas. 5)], 1.5.9, 1.5.10 (EVE Precision & Range)					
2.3.5.2				No Observatory subsystem shall generate a magnetic field greater than TBD (100nTesla??) at an equivalent distance to that on the Observatory between the component and EVE OFS instrument.	Magnetic field measured at component location. Verification of this requirement may be by analysis or test on a case-by-case basis	CONTAM, INSTR, ELEC, Electrical subsystems, MATL	Lev. 1 [Precision (Science Meas. 5)], 1.5.9, 1.5.10 (EVE Precision & Range)					
2.3.5.3				The Observatory shall not generate a magnetic field greater than TBD (100 nTesla??) at the EVE OFS instrument location		CONTAM, INSTR, ELEC, Electrical subsystems, MATL	Lev. 1 [Precision (Science Meas. 5)], 1.5.9, 1.5.10 (EVE Precision & Range)					
2.3.5.4				All observatory subsystems (except as noted above) shall be able to meet full mission requirements in the presence of a magnetic field of 40 µTesla (TBR)	Estimated magnetic field at expected minimum Geo perigee (185 Km)	CONTAM, INSTR, ELEC, Electrical subsystems	2.3.1.1 (Min perigee)					
2.4		**Launch Vehicle (LV)**	**The launch vehicle (LV) shall provide sufficient performance capability and reliability to place SDO Observatory in the desired initial transfer orbit**	N/A	N/A	LV, FLT DYN, PERF ASSUR.	**2.1.1 (Orbit)**					
2.4.1		LV Selection		The Observatory design and ops concept shall be compatible with the use of the DELTA 4040 or ATLASV 401 LV configuration	Reflects LV configuration options	ALL	2.1.1 (Orbit)					
2.4.2		LV Performance	The LV shall deliver the Observatory to a transfer trajectory from which the Observatory-supplied propulsion system shall modify the orbit to its desired final profile	N/A	N/A	LV, FLT DYN	2.1.1 (Orbit)					
2.4.2.1				The LV shall provide an 3200 kg (TBR) throw weight to a 28.7 deg (ETR) inclination orbit	Reflects estimated Observatory mass allocation; Preliminary allocation deliberately limited below LV capability of 3900 in order to leave open co-manifest options	LV, FLT DYN	2.1.1 (Orbit)					
2.4.2.2				The LV orbit insertion errors shall be no greater than **TBD** (as defined in the "DELTA IV PAYLOAD PLANNERS GUIDE").	Expect that LV ICD will supercede LV PPG as controlling configured document when available. AO assumptions indicated that Observatory will not budget fuel to correct for inclination insertion errors- counting on LV to provide adequate insertion trajectory. PPG addresses deviation range in inclination, apogee, perigee, and argument of perigee.	LV, FLT DYN, Electrical subsystems	2.1.1 (Orbit), 2.4.1 (LV)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.4.2.3				The minimum perigee for initial orbital insertion trajectory shall nominally be 185 km.	Low perigee passes result in various effects on the Observatory and spacecraft performance (Atomic oxygen degradation, aeroheating, RW saturation, magnetic field effects, etc)	LV, FLT DYN	2.1.1 (Orbit), 2.4.1 (LV)					
2.4.2.4				The LV-induced initial Observatory tipoff rates shall be no greater than 1, 2, 2 deg/sec (3 sigma) (x, y, z) at Observatory separation	Reflects design requirement by which attitude control system must be able to unload initial post-separation momentum	LV, FLT DYN	2.1.1 (Orbit), 2.4.1 (LV)					
2.4.3		LV Interfaces	The launch vehicle (LV) shall provide specified mechanical and electrical interfaces to the Observatory and the ground system for testing, verification, and flight ops			LV, MECH, PWR, RF, C&DH, ELEC, GSE	2.7.2 (Verify)					
2.4.3.1		Observatory umbilical connection	The LV shall provide an umbilical interface for power and communications from the Observatory to ground control station via the blockhouse in order to allow remote test and monitoring of the Observatory while it is integrated to the LV			LV, MECH, PWR, RF, C&DH, ELEC, GSE	2.7.2 (Verify)					
2.4.3.2		Environmental conditioning	The LV shall provide access for the necessary environmental conditioning of the Observatory while it is integrated to the LV			LV, MECH, PWR, INSTR, CONTAM	2.3 (Envir)					
2.4.3.2.1				The LV fairing shall be Boeing VC6 (visibly clean, Level 6) or equivalent	Required to maintain contamination and environmental control reflected in Contamination Control plan	LV, MECH, CONTAM	2.3 (Envir)					
2.4.3.2.2				The LV shall provide access for a continuous filtered purge of grade TBD nitrogen up to T-0 (umbilical break-away line)	Required to maintain contamination and environmental control reflected in Contamination Control plan	LV, MECH, CONTAM	2.3 (Envir), 2.2.5 (Safety)					
2.4.3.2.3				The LV shall provide continuous Class 1,000 HEPA filtered air supply into fairing up to launch	Required to maintain contamination and environmental control reflected in Contamination Control plan	LV, MECH, CONTAM	2.3 (Envir), 2.2.5 (Safety)					
2.4.3.2.4			The LV interface shall provide access and an implementation approach for battery A/C to maintain Observatory batteries within required operational and safety margins		Reflects Battery Handling Plan (doc # TBD) and SDO Launch site operations plan	LV, MECH, PWR, CONTAM	2.3 (Envir), 2.2.5 (Safety)					
2.4.3.3		Separation signals										
2.4.3.3.1				The Observatory shall support the use of 3 separation signals from the LV third stage to the Observatory		LV, MECH, ELEC	4.2.1 (Acquisition))					
2.4.3.4		LV Access	The LV shall provide vehicle access to allow servicing of Observatory components (battery, prop system, Instruments, etc) as required on the launch pad with the fairing in place			LV, MECH	2.7.2 (Verif), 2.7.5 (Safety)					
2.5		**Mission Implementation/ Ops Concept**	**The SDO Ops Concept shall combine the Science collection and distribution requirements as well as the Observatory design implementation approach and constraints into an implementation plan that allows successful mission planning and operation**			ALL	Lev.1 [Sci Req 1-6], 1.1 (Sci Obs), 1.2 (Data Capture & Compl)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.5.1		Continuous Contact	The Observatory shall maintain (near) continuous science data downlink contact with the ground station in order to capture the science data within the capture budget		Traced from both the high DL data rates required as well as the prohibitive impact of implementing a SSR approach to both store then DL the data at a rate that would clear the SSR in a reasonable time frame. Any gaps in DL coverage must be encompassed within the data capture budget margins.	C&DH, GND, APS, RF, GN&C	Lev.1 [Sci Req 1-6], 1.2 (Data Capture & Compl), 1.6 (Cadence)					
2.5.2		Dedicated Ground Station Sites	The Mission implementation shall employ the use of a dedicated ground station to meet science data downlink completeness requirements		Reflects the high data rate and data capture budget implementation approach	GND	Lev.1 [Sci Req 1-6], 1.2 (Data Capture & Compl), 1.6 (Cadence)					
2.5.3		Data Completeness	The Mission implementation shall meet the data capture and completeness requirements needed to meet the science requirements		Addressed through the use of a configured Data Capture Budget (Doc # TBD) which allocates data loss throughout the data capture and distribution components	INSTR, C&DH, GN&C, APS, RF, GND	Lev.1 [Sci Req 1-6], 1.2 (Data Capture & Compl)					
2.5.4		Data Delivery	The Ground Stations shall route the science data directly to the Instrument Science Operations Centers (SOCs) after receiving the data (per data latency requirements in 5.2.6.6)		Addresses the need for continuous transport of science data directly to the SOCs. Observatory housekeeping data will be routed to the SOCs via the MOC.	GND, INSTR	Lev.1 [Science Objectives D & E: Support Forecasting]					
2.5.5		Observatory Pointing and Jitter Control	The combination of the Observatory attitude control, the Observatory and Instrument mechanical and thermal design, and Instrument internal pointing compensation shall provide the necessary pointing control and jitter performance required to meet the instrument science requirements			INSTR, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.1				The Observatory shall designate KCOR as the science reference boresight and shall point this reference boresight to the target (sun center) to an absolute accuracy of 10 arcsec (3 sigma) using the AIA GT signal	Since KCOR has no internal pointing capability and has the most severe science degradation impacts due to pointing errors, the observatory shall use the GT signal, with a suitable bias applied, to point KCOR at sun center	SHARPP, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.2				The AIA Magritte and SPECTRE boresights will be maintained within 70 arcsec (3 sigma) in the Y and Z axes over a period of not less than one week		SHARPP, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.3				The HMI boresight will be maintained within 200 arcsec of sun center through a combination of on-ground alignment and optical bench stability		HMI, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.4				The HMI boresight will be adjusted to within 14 arcsec (3 sigma) through the adjustment of the HMI on-orbit alignment system (legs), internal guiding correction provided by the HMI Image Stabilization System and the Spacecraft pointing control	14 arcsec is the limit of the HMI image motion compensation system	HMI, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.5				The Observatory shall maintain the EVE boresight to an absolute accuracy of 450 arcsec (3 sigma) to the target (sun center) through a combination of on-ground alignment accuracy and optical bench stability	The Spacecraft will maintain the EVE mounting surface (reference optical surface) to within an accuracy of 150 arcsec (3 sigma) to the target (sun center); need to determine EVE absolute pointing req (see 3.1.1.1)	EVE, MECH, GN&C, APS	Lev.1 [Sci Req 1-6], 1.3 (Ang Res. & Coverage)					
2.5.5.6				The Observatory jitter at the HMI and SHARPP mounting interface to the Observatory optical bench shall be 5 arcsec (3 sigma) over frequencies of 0.02 Hz to 50 Hz in the X, Y & Z axes and 1 arcsec (3 sigma) above 30 Hz	Addresses requirement for control of torque disturbances and torque noise	GN&C, MECH, APS	1.3 (Ang Res & Coverage), 2.5.5 (Pointing & Jitter Control), 2.6.4 (Attitude Control)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.5.5.7				EVE requires a stability of 140 arcsec (TBR) over a period of minutes to days (TBR).	EVE defines stability as longer period drift in the control point (in the control bandwidth of the S/C) and alignment, both preflight and inflight offset errors of a sensor bore to the 'reference' control point (See section 4). Can we come up with an acceptable definition?	GN&C, MECH, APS	1.5 (Precision), 2.5.5 (Pointing & Jitter Control), 2.6.4 (Attitude Control)					
2.5.6		Spacecraft Autonomy	The Spacecraft shall possess sufficient onboard autonomy to allow basic fault detection and correction.		Addresses the need for onboard autonomy for basic operational reliability and fault tolerance	C&DH, GN&C, FSW, PWR	2.2.1 (Mission Life), 2.2.2 (Fault Tol)					
2.5.7		Critical Telemetry Monitoring	All mission and time critical activities (separation, solar array & HGA deployment, acquisition, critical Delta-V maneuvers, etc) shall be performed within ground contact to allow telemetry monitoring			C&DH, FSW, RF, GND	2.2.1 (Mission Life), 2.2.2 (Fault Tol)					
2.5.8		Mission Phases	The SDO Observatory and mission shall be designed to support the various phases of SDO flight operations									
2.5.8.1			The SDO Observatory and mission shall be designed to support Launch and Acquisition		Phase covering pre-launch configuration until Observatory is power-positive and pointing at the Sun							
2.5.8.2			The SDO Observatory and mission shall be designed to support In-Orbit Checkout		Phases covering the first weeks to check out and calibrate the Observatory. Portions of this will occur concurrently with the Orbit Circularization phase							
2.5.8.3			The SDO Observatory and mission shall be designed to support Orbit Circularization		Occurs during In-Orbit Checkout and covers the mission elements required to conduct several apogee thruster burns to raise orbit to Geo							
2.5.8.4			The SDO Observatory and mission shall be designed to support Nominal Mission Mode		Primary on-station operational phase, where science data is collected and transferred to the ground station, where it is distributed to the SOCs. Observatory housekeeping data is also collected and transferred to the MOC for monitoring/trending/etc and distribution to the SOCs							
2.5.8.5			The SDO Observatory and mission shall be designed to support Periodic Calibrations and Housekeeping		Interruptions in minimal science phase needed to maintain science quality through calibration observations and alignment adjustments							
2.5.8.6			The SDO Observatory and mission shall be designed to support Eclipse periods		Consequence of Geo orbit- principal Observatory requirement is to survive and minimize impact on science operations							
2.5.8.7			The SDO Observatory and mission shall be designed to support Stationkeeping and Momentum Management		Required operations to keep observatory within designated orbital position and angular momentum capabilities							
2.5.8.8			The SDO Observatory and mission shall be designed to support Safehold and Emergency modes		Required to place the Observatory in a safe mode in the event of an anomaly and allow anomaly investigation and correction from the ground							
2.5.8.9			The SDO Observatory and mission shall be designed to support Observatory Disposal		Required to dispose of Observatory per NASA guidelines							
2.6		**Standard Spacecraft Services**	**The SDO Spacecraft shall provide standard spacecraft functions and services required for orbital science operations**									

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.6.1		Structure	The Spacecraft mechanical structure shall accommodate the requirements of the Launch Vehicle, Spacecraft and Instrument			MECH	2.1 (Orbit), 2.4 (LV)					
2.6.1.1			All Observatory components shall be allocated and remain within a specified mass budget		Requirement will be tracked by use of configured mass resources budget spreadsheet (Doc # TBD) ; changes to mass budget allocation only by project approved configuration change request	All Observatory Components	2.1 (Orbit), 2.4 (LV), 2.4.2.1 (Observ. Mass Allocation)					
2.6.2		Thermal Control	The Spacecraft shall provide a thermal environment which meets limits required by each element of the Observatory for all mission phases			THERM, MECH, All Observatory Components	2.1 (Orbit)					
2.6.3		Power Distribution	The Spacecraft shall provide and distribute sufficient power to support all phases of the SDO mission			PWR	2.1 (Orbit), 2.2.1 (Mission Life)					
2.6.3.1			All Observatory components shall be allocated and remain within a specified power budget (which adresses end-of-life power requirements)		Requirement will be tracked by use of configured power budget spreadsheet; changes to power budget allocation only by project approved configuration change request	All Observatory Components	2.1 (Orbit)					
2.6.4		Guidance, Navigation, & Control	The Observatory and Ground System shall provide the knowledge & pointing capability to determine and control Observatory orientation, position, and velocity through all phases of the mission within the constraints of mission science goals			GN&C, FLT DYN, GND	2.1 (Orbit)					
2.6.5		Communications	Observatory shall have the capability to receive and execute commands and transfer data between the spacecraft and ground system in order to carry out mission operations			C&DH, FSW, RF, GND	2.1 (Orbit)					
2.6.6		Data Processing, Storage, & Timekeeping	The Spacecraft shall possess sufficient data processing and storage capability and Spacecraft timekeeping functions to meet mission operations requirements			C&DH, FSW	2.1 (Orbit)					
2.6.7		Housekeeping Telemetry	The Spacecraft shall downlink sufficient housekeeping engineering data to the ground to allow nominal spacecraft operation and performance evaluation, as well as anomaly investigation and resolution		Addresses the need for Observatory telemetry for ground monitoring and troubleshooting during testing and flight	ALL	2.1 (Orbit), 2.2.2 (Fault Tol)					
2.6.8		Spacecraft Architecture	The Observatory shall utilize the 1553 bus as the primary method for distributing observatory commands and collecting Observatory telemetry for downlink									
2.7		**Development Approach**	N/A	N/A	N/A							
2.7.1		Performance Assurance & Safety	The development of flight hardware, software, and GSE for the SDO mission shall adhere to the SDO Mission Assurance Requirements (MAR) document	N/A	N/A	ALL	2.1.2 (Mission Life), 2.6 (Standard S/C Services)					
2.7.2		Verification	The Observatory shall undergo sufficient testing or analysis to verify that it meets all Mission requirements	N/A	N/A	ALL	2.1.2 (Mission Life), 2.6 (Standard S/C Services)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
2.7.2.1			The Observatory shall be subjected to environments prior to launch as part of a comprehensive test program to verify that it meets launch and mission requirements based on the SDO environmental verification test matrix			ALL	2.1 (Orbit), 2.6 (Standard S/C Services)					
2.7.2.2			The design shall provide for adequate visibility to accommodate effective subsystem and system functional and performance verification at all stages of development			ALL	2.6 (Standard S/C Services), 2.7.2 (Verification)					
2.7.2.2.1			Sufficient telemetry shall be available through the 1553 bus to fully verify electrical subsystem development and system performance. Requirement does not cover the monitoring and verification of high rate instrument science data over the 1553 bus		Derived from development philosophy of reducing effort and risk by designing system architecture and development approach for the same testability process that can be used throughout the various Observatory development phases	Electrical subsystems	2.6 (Standard S/C Services), 2.7.2 (Verification)					
2.7.2.2.2			Critical internal test points shall be identified by all subsystems and instruments and brought out to external test points and/or skin connectors to allow monitoring during test		Addresses the need for intermediate test points for verification as well as tools for ground test/debugging process both at subsystem and Observatory level	Electrical subsystems	2.6 (Standard S/C Services), 2.7.2 (Verification)					
2.7.3		Configuration Management	SDO hardware, software and operations concept development shall employ procedures which enable the establishment and tracking of product implementation traceability to the configured designs and approaches	N/A	N/A	ALL	2.6 (Standard S/C Services), 2.7.2 (Verification)					
2.7.4		Electrical Specification	The SDO subsystems, instruments, components and GSE shall adhere to the electrical and electronic requirements specified in the SDO Electrical Systems Specification (doc # TBD)		N/A	ALL	2.7.3 (CM), 2.7.2 (Verification)					
2.7.5		Mechanical Specification	The SDO subsystems, instruments, components and GSE shall adhere to the mechanical requirements specified in the SDO Mechanical Subsystem Specification (doc # **TBD**)			All Observatory Components	2.7.3 (CM), 2.7.2 (Verification)					
2.7.6		Thermal Specification	The SDO subsystems, instruments, components and GSE shall adhere to the thermal requirements specified in the SDO Thermal Subsystem Specification (doc # **TBD**)			All Observatory Components	2.7.3 (CM), 2.7.2 (Verification)					
2.7.7		End-of Life Disposal	The Observatory design shall provide the capability for controlled end of life disposal in accordance with NASA guidelines (NSS 1740.14, NPD 8710.3, revisions as of Jan 2003)			GN&C, FLT DYN, PROP, MECH, GND	2.2.5 (Safety), NASA EOL Guidelines					
3		**Instrument Requirements**										
3.1		**EVE**										
3.1.1		Alignment & Stability										
3.1.1.1				The EVE components shall meet the performance requirements specified in the SDO Observatory Point and Alignment Budget (Doc. # TBD).		EVE	1.5 (Precision)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
3.1.1.2				During nominal science operations, the EVE instrument shall limit any disturbance contribution to the Observatory jitter allocated in theSDO Observatory Pointing and Alignment Budget (Doc # TBD)		EVE	2.5.5 (Pointing & Jitter Control)					
3.1.2		Spectral Resolution		MEGS A shall provide solar irradiances 0.5 - 36 nm with 0.1 nm resolution, MEGS B shall provide 35 - 105 nm solar irradiances with 0.1 nm resolution, OFS shall provide relative solar irradiance measurements (TBD) nm with > 1 nm resolution, ESP shall provide solar irradiance measurements with 0.2nm resolution.	EVE may prefer to break out the precision, accuracy and time cadence for each sensor as well. They also may prefer to state this with less detail.	EVE	1.4 (Spectral Resolution)					
3.1.3		Timing										
3.1.3.1			The EVE Instrument shall utilize the relative Spacecraft timing signals and accuracy provided over the 1553 bus		EVE has a need to receive absolute time broadcasts over the 1553 bus in addition to relative time pulses.	EVE	1.5 (Precision)					
3.1.4		Data Completeness										
3.1.4.1				The EVE science data bit error rate shall be less than $2.5x10^{-7}$ (TBR).	Reflects the instrument component of the EVE 99.6% data science completeness budget.	EVE	2.5.3 (Data Capture & Compl)					
3.1.5		Interface Requirements										
3.1.5.1				The EVE science data shall not exceed of maximum data rate allocation of 2 Mbps over the IEEE 1355 high rate science data bus	Defines the EVE allocation of the 130 Mbps (150 Mbps post-encoding & margin) science data downlink	EVE, C&DH	1.6.6 (Cadence)					
3.1.5.2			The EVE instruments shall adhere to the high speed bus data rate and interface requirements detailed in the SDO/EVE High Rate Science Bus Interface Specification (Doc # TBD)			EVE, C&DH	1.2.2 (Data Capture & Compl)					
3.1.5.3			The EVE Instrument shall receive all Commands and distribute all housekeeping telemetry over the Observatory 1553 interface			EVE, C&DH, FSW	2.6.8 (S/C Arch)					
3.2		**HMI**										
3.2.1		Alignment & Jitter										
3.2.1.1				The HMI components shall meet the performance requirements specified in the SDO Observatory Pointing and Alignment Budget (Doc # TBD).		HMI	1.3.1, 1.3.2 (Ang Res & Coverage)					
3.2.1.2				Deleted								
3.2.1.3				The HMI instrument shall provide 40 dB disturbance rejection at the focal plane in pitch and yaw with a servo bandwidth of >30 Hz (TBR).	In order to meet 1 arcsecond image resolution, the image jitter during exposure must be less than 0.1 pixel (0.05 arcsecond). Based on attenuation required from 5 arcsec spacecraft jitter req to HMI 1/10 pixel (3 sigma) jitter req	HMI	1.3.1, 1.3.2 (Ang Res & Coverage)					
3.2.1.4				The range of the ISS (image stabilization system) for both drift and jitter combined shall be at least +/-14 by +/- 17 arcsec .	The HMI internal pointing must be capable of TBD arcsecond adjustment over periods of 1 week to compensate for medium-term drift relative to the spacecraft boresight.	HMI	1.3.1, 1.3.2 (Ang Res & Coverage)					
3.2.1.5				The HMI instrument shall utilize adjustable rear mounting legs to provide pitch and yaw adjustment of the HMI alignment with respect to the Observatory over an adjust range of +/- 200 arcseconds with 2 arcsecond increments.	The HMI instrument pointing must be capable of TBD arcsecond adjustment to provide initial co-alignment with the spacecraft boresight and to compensate for relative drift over the course of the mission.	HMI	1.3.1, 1.3.2 (Ang Res & Coverage)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
3.2.1.6				During nominal science operations, the HMI instrument shall limit any disturbance contribution to the observatory jitter allocated in the SDO Observatory Pointing and Alignment Budget (Doc. # TBD)	Opening the door and moving the legs (both done very infrequently) may make larger disturbances.	HMI	2.5.5 (Pointing & Jitter Control)					
3.2.2		Angular Resolution										
3.2.2.1				The HMI Instrument shall provide a camera with at least 4096x4096 pixels to achieve the required dopplergram, longitudinal and vector magnetogram resolutions.	The HMI instrument shall provide a camera with at least 960*2/.5= 3840 pixels to achieve the required resolution	HMI	1.3.1, 1.3.2 (Ang Res & Coverage)					
3.2.3		Timing										
3.2.3.1				The basic reference clock controlling the HMI observing cycle shall be to maintain a stability of 10^-6 over periods of days, with adjustments to be made smoothly in order to insure that there are no discontinuities or step changes in the clock.	An HMI reference clock may be provided internally to the instrument. HMI must receive the spacecraft absolute time broadcasts in order to initially set the internal clock, and to monitor drifts of the HMI internal clock relative to the spacecraft clock.	HMI	1.5.1 (Precision)					
3.2.4		Data Completeness										
3.2.4.1				The HMI science data bit error rate shall be less than $1x10^{-10}$ (TBR)	HMI's allocation of the 99.99% data completeness.	HMI	2.5.3 (Data Capture & Compl)					
3.2.5		Interface Requirements										
3.2.5.1				Any compression of the HMI science data shall be in a manner such that HMI does not exceed a maximum data rate allocation of 55 Mbps over the IEEE 1355 high rate science data bus	Defines the HMI allocation of the 130 Mbps (150 Mbps post-encoding & margin) science data downlink	HMI, C&DH	1.6.1 , 1.6.2, 1.6.3 (Cadence)					
3.2.5.2			Any compression of the HMI data shall be in a manner that preserves the data quality commensurate with the science analysis and completeness requirements		This addresses need for HMI science data compression to meet the science data rate req while still meeting data completeness req	HMI	1.2.2 (Data Capture & Compl)					
3.2.5.3			The HMI instruments shall adhere to the high speed bus data rate and interface requirements detailed in the SDO/HMI High Rate Science Bus Interface Specification (Doc # TBD)			HMI, C&DH	1.2.2 (Data Capture & Compl)					
3.2.5.4			The HMI Instrument shall receive all Commands and distribute all housekeeping telemetry over the Observatory 1553 interface			HMI, C&DH, FSW	2.6.8 (S/C Arch)					
3.3		**SHARPP**										
3.3.1		Alignment & Jitter										
3.3.1.1				The SHARPP components shall meet the performance requirement specified in the SDO Observatory Pointing and Alignment Budget (Doc. # TBD).		SHARPP	1.3.1, 1.3.2 (Ang Res & Coverage)					
3.3.1.2				Deleted								
3.3.1.3				The SHARPP AIA Instruments shall provide 12 dB disturbance rejection from mounting feet to focal plane up to a bandwidth of 30 Hz	Based on attenuation required from 5 arcsec spacecraft jitter req to AIA 1.32 arcsec (3 sigma) jitter req	SHARPP	1.3.3 (Ang Res & Coverage)					
3.3.1.4				SHARPP shall provide two guide telescopes (primary and redundant units), each with a noise equivalent angle of 1 arcsec and an update frequency to the spacecraft of at least 10 Hz.		SHARPP	1.3.4 (Ang Res & Coverage)					
3.3.1.5				During nominal science operations, the SHARPP instrument shall limit any disturbance contribution to the Observatory jitter allocated in the SDO Observatory Pointing and Alignment Budget (Doc. # TBD)		SHARPP	2.5.5 (Pointing & Jitter Control)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
3.3.1.6				The Guide Telescope shall be designed such that the science sun acquisition can be performed given an initial pointing error of 60 arcsec (3 sigma) in the y and z axes.		SHARPP	2.5.5 (Pointing and Jitter Control)					
3.3.2		Angular Resolution										
3.3.2.1				SHARPP AIA Instruments shall provide cameras with a width of at least 1.4*960*2/.66=4073 pixels to achieve the required atmospheric image resolution		SHARPP	1.3.3 (Ang Res & Coverage)					
3.3.2.2				SHARPP KCOR Instrument shall provide a camera with a width of at least 15*960*2/14 =2057 pixels to achieve required coronagraphic image resolution	Initial information indicates that SHARPP will only be 2048 by 2048- need to address this	SHARPP	1.3.4 (Ang Res & Coverage)					
3.3.3		Timing										
3.3.3.1			The SHARPP Instrument shall utilize the relative Spacecraft timing signals and accuracy provided over the 1553 bus	Relative time accuracy .01 seconds		SHARPP	1.5 (Precision)					
3.3.3.2				Absolute time accuracy 0.1 seconds.		SHARPP	1.5 (Precision)					
3.3.4		Data Completeness										
3.3.4.1				The SHARPP science data bit error rate shall be less than $5x10^{-8}$ (TBR)	Reflects the instrument component of the 99.9% data science completeness budget (1x10-7 total budget)	SHARPP	2.5.3 (Data Capture & Compl)					
3.3.5		Interface Requirements										
3.3.5.1				The SHARPP science data shall not exceed of maximum data rate allocation of 72 Mbps over the IEEE 1355 high rate science data bus	Defines the SHARPP allocation of the 130 Mbps (150 Mbps post-encoding & margin) science data downlink	SHARPP, C&DH	1.6.4 , 1.6.5 (Cadence)					
3.3.5.2			Any compression of the SHARPP data shall be performed in such a manner that SHARPP preserves the data quality commensurate with the science analysis and completeness requirements.		This addresses need for SHARPP science data compression to meet the science data rate req	SHARPP	1.2.2 (Data Capture & Compl)					
3.3.5.3			The SHARPP instruments shall adhere to the high speed bus data rate and interface requirements detailed in the SDO/SHARPP High Rate Science Bus Interface Specification (Doc # TBD)			SHARPP, C&DH	1.2.2 (Data Capture & Compl)					
3.3.5.4			The SHARPP Instrument shall receive all Commands and distribute all housekeeping telemetry over the Observatory 1553 interface			SHARPP, C&DH, FSW	2.6.8 (S/C Arch)					
3.3.6		Dynamic Range		SHARPP AIA instruments shall provide cameras with a dynamic range of at least 13 bits. SHARPP KCOR shall provide a camera with a dynamic range of at least 14 bits.	This addresses need for SHARPP science data to meet the required contrast levels based upon photon statistics, noise and expected count rates.	SHARPP	1.5 (Precision)					
4		**Spacecraft Requirements**										
4.1		**Structural /Thermal**										
4.1.1		Launch Vehicle Accommodation	The mechanical structure of the Observatory shall accommodate the constraints of the launch vehicle	N/A	N/A	MECH	2.4 (LV)					
4.1.1.1				The SDO Observatory shall fit within the static and dynamic envelope of the Delta 4040 or the ATLASV 401 fairing	Reference the "DELTA IV PAYLOAD PLANNERS GUIDE" for this and the subsequent req	MECH	2.4 (LV)					
4.1.1.2				The SDO Observatory shall meet the interface requirements of the Delta 4040 or the ATLASV 401 PAF		MECH	2.4 (LV)					
4.1.1.3				The stowed Observatory shall have a C.M. < 4 m above the separation plane		MECH	2.4 (LV)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.1.1.4				The SDO Observatory shall be designed to meet the mechanical, thermal, and EMI requirements of the Delta 4040 or the ATLASV 401 LV as defined in the "DELTA IV PAYLOAD PLANNERS GUIDE"		MECH	2.4 (LV)					
4.1.1.5				The stowed Observatory shall be static and dynamically balanced to meet the requirements defined in the "DELTA IV PAYLOAD PLANNERS GUIDE"		MECH	2.4 (LV)					
4.1.2		**Spacecraft and Instrument Accommodation**		N/A	N/A		2.6.1 (Stand S/C Services- Mech)					
4.1.2.1			The structure shall provide sufficient area to mount all electronics boxes and components and provide necessary provision for required thermal radiators			MECH, THERM	2.4 (LV)					
4.1.2.2			The Observatory shall be designed such that the CM migration over the life of the mission does not eliminate attitude control authority from any required thruster		All SDO mass changes shall be regularly monitored and assessed against the CM requirement and a CM reassessment conducted when warranted to verify that CM still remains within specified parameters	MECH, GN&C, PROP	2.4 (LV), 4.2.4 (Delta-V)					
4.1.2.3				The structure shall be electrically conductive to a measured resistance of less than 2.5 mOhms across electronic component mounting surfaces	Addresses Observatory electronics grounding requirements	MECH, THERM, ELEC	2.7.4 (Elec)					
4.1.2.4			The structure shall provide a clear field of view for all instrument and relevant components (Instrument CCD thermal radiators, ACS sensors, thrusters, and omni and high gain antennas) within the specified parameters required by that component			MECH, THERM	2.6.1 (Stand S/C Services- Mech), 3.1.1, 3.2.1, 3.3.1 (Instr FOV)					
4.1.2.5				Thruster plume impingement avoidance angle from all Observatory components shall be > 30 deg (TBR) half angle measured from the center line of the thruster nozzle	Addresses plume impingement resulting in disturbance effects. Contamination is affected by this requirement and needs to be evaluated	CONTAM, PROP, MECH, GN&C	Lev. 1 [Precision (Science Meas. 1-6)], 2.2.1 (Mission Life)					
4.1.2.6				Thruster plume impingement heating effect avoidance angle from all Observatory components shall be > 45 deg (TBR) half angle measured from the center line of the thruster nozzle	Addresses thruster heating effects; may be waived if appropriate thermal protection materials are used. Contamination is affected by this requirement and needs to be evaluated	CONTAM, PROP, MECH, GN&C, THERM, MATL	Lev. 1 [Precision (Science Meas. 1-6)], 2.2.1 (Mission Life)					
4.1.2.7			The Observatory structure shall be designed for appropriate shipment accommodation		Vehicle shipment, lifting & handling, etc	MECH	2.6.1 (Stand S/C Services- Mech)					
4.1.3		**Thermal Monitoring and Control**		N/A	N/A		2.6.2 (Stand S/C Services- Therm)					
4.1.3.1			The Observatory thermal control system shall be designed to provide Observatory components with thermal radiators (where required) with adequate radiator area to keep component thermal rejection requirements			THERM, MECH	2.6.2 (Stand S/C Services- Therm)					
4.1.3.2			The Observatory shall provide operational temperature control capability in order to allow the Observatory to maintain the Observatory components and structure within operational ranges			THERM	2.6.2 (Stand S/C Services- Therm)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.1.3.3			The Observatory shall provide autonomous temperature control within survival temperature limits at all times even in the event of operational heater monitoring and control failure			THERM	2.6.2 (Stand S/C Services-Therm)					
4.1.3.4				Survival heaters shall be sized for a minimum bus voltage of 24V (TBR) and above this voltage they shall keep components within their survival limits indefinitely	Based on minimum bus voltage due to battery cell failures	THERM, PWR	2.6.2 (Stand S/C Services-Therm), 2.1.2.2 (Fault Tol)					
4.1.3.5				Deleted								
4.1.3.6				Deleted								
4.1.3.7				Deleted								
4.1.3.8				Deleted								
4.1.3.9				Deleted								
4.1.3.10				Deleted								
4.1.3.11				Deleted								
4.1.3.12				Deleted								
4.1.3.13			Nominal on-station Observatory maneuvers shall not result in direct sunlight on Instrument thermal radiators for a time period such that critical internal instrument temperatures rise beyond acceptable levels		Addresses instrument keep-out zones during pre-planned on-station maneuvers	GN&C, THERM	1.2.1 (Data Capture & Compl), 4.1.3.9, 4.1.3.10 (Instr Therm limits)					
4.1.3.13.1				Stationkeeping and momentum unwading maneuvers at GEO shall be designed to limit the maximum angle between the Sun and the x-axis to less than 45 degrees (TBR), for a duration of no longer than 30 minutes (TBR). This constraint may be violated in the event of a thruster failure or spacecraft emergency.		GN&C, THERM	1.2.1 *Data Capture and Completeness, 4.1.3.9, 4.1.3.10 (Instrument Thermal Limits)					
4.1.3.14				Deleted								
4.1.3.15				Deleted								
4.1.3.16				Deleted								
4.1.3.17				Deleted								
4.1.3.18				Deleted								
4.1.3.19				Deleted								
4.1.3.21				The Spacecraft shall provide temperature monitoring thermistors for all Observatory components and critical structural surfaces in order to maintain knowledge of Observatory temperatures		THERM, Electrical Subsystems	2.6.2 (Stand S/C Services-Therm), 22.6.7 (H/K Telemetry)					
4.1.3.22				The Instrument optical bench and instrument telescope assemblies shall be designed to survive any angle of offpointing after launch and through orbit circularization for period 1.5 hrs (TBR) and return to proper alignment with no degradation of science performance	Addresses worst case offpointing for GEO-insertion maneuvers and the resultant thermally induced alignment errors. Need to clarify whether Instruments are powered or unpowered during this time	MECH, THERM, INSTR, GN&C	1.3 (Ang Res & Coverage), 4.1.2.4 (Struct Instr Accomm)					
4.1.4		**Instrument Optical Bench**	The Observatory structure shall provide an optical bench to mount all instrument telescopes & star trackers in such a manner that meets mounting, FOV, and thermal requirements	N/A	N/A	MECH, THERM	2.6.1. 2.6.2 (Stand S/C Services- Mech & Therm)					
4.1.4.1			The instrument optical bench shall provide all instrument telescopes with an optical FOV free of obstruction and glint from other portions of the Observatory		Instrument FOV requirements detailed in Instrument/Observatory mechanical ICDs (doc #'s **TBD**). See Instrument FOV requirements in Section 3	MECH	4.1.2.4 (Struct Instr Accomm)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.1.4.2			The instrument optical bench shall provide all instrument thermal radiators with suitable thermal FOV required to maintain instrument CCDs and telescope electronics to a temperature within their specified operating temperature ranges.		See 4.1.3.10 for instrument CCD thermal reqs	MECH, THERM	4.1.2.4 (Struct Instr Accomm)					
4.1.4.3			The instrument optical bench shall provide a stable mounting alignment environment between all instruments and the guide telescope that meets the mission pointing requirements during nominal operations		Reflects the instrument mechanical alignment component of the overall instrument pointing budget	MECH	1.3 (Ang Res & Coverage), 4.1.2.4 (Struct Instr Accomm)					
4.1.4.3.1			Alignment Errors	All alignment errors between each of the instrument mounting interfaces and the GT interface shall meet the performance requirement specified in the SDO Observatory Alignment Budget (Doc. Number TBD).	Static error sources may include 1G effects, on-orbit thermal settling, launch shifts, measurements errors, etc	MECH	1.3 (Ang Res & Coverage), 4.1.2.4 (Struct Instr Accomm)					
4.1.4.3.2				Deleted								
4.1.4.3.3			High Frequency Alignment Errors	The out of phase relative motion between the SHARPP instrument boresights and the GT boresights shall not exceed an amplitude of TBD (0.05 arcsec??) for frequencies between 0.1 Hz and 10 Hz	Addresses the need to avoid significant modes that would interfere with the SHARPP instrument motion compensation system (HMI has own internal closed-loop IMC system, while EVE has no jitter requirements)	MECH	1.3 (Ang Res & Coverage), 4.1.2.4 (Struct Instr Accomm)					
4.1.4.3.4				The instrument optical bench design shall allow all instruments to return to within their specified alignment within 60 minutes after a planned maneuver or eclipse	Based on preliminary Instrument inputs. Reflects the thermal-induced alignment error (instrument optics, mechanical alignment) during eclipses, offpointing, maneuvers, etc This also places a requirement on sun impingement and shadowing due to offpointing.	MECH, THERM,	1.3 (Ang Res & Coverage), 4.1.2.4 (Struct Instr Accomm), 1.2 (Data Capture & Compl)					
4.1.4.4			Instrument Ground Test Access	The instrument optical bench shall provide access for all required GSE and test & support equipment		MECH, GSE	4.1.2.4 (Struct Instr Accomm)					
4.1.4.4.1				The Instrument telescopes shall have access provided for all GSE and purge lines required during I&T	Req may need to be modified to indicate that all purge lines connect to single accessible connector plate	MECH, CONTAM	2.3 (Envir), 4.1.2.4 (Struct Instr Accomm)					
4.2		**Attitude Control & Determination**										
4.2.1		**Acquisition**	The Observatory shall have the capability to acquire the sun and maneuver to a sun pointing orientation	N/A	N/A		2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.1.1				The Observatory shall be pointed to the sun within the accuracy defined in 4.2.6.1 from any initial orientation within 30 minutes after a spacecraft pointing anomaly or a specific ground command to enter the sun acquisition state		GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.1.2				The Observatory shall be pointed to the sun within the accuracy defined in 4.2.6.1 from any initial orientation within 45 minutes after Observatory separation from the LV.	This requirement infers 15 minutes unload momentum with use of thrusters (as referenced in 4.2.5.1) and 30 minutes to acquire sun. Req driven by battery charge depletion concerns. Safehold pointing accuracy defined in 4.2.6.1.	GN&C, LV	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control), 2.4.2.4 (LV Perf)					
4.2.1.3				Sun acquisition shall be accomplished without the use of thrusters for initial post LV separation rates of up to 1, 2, 2 deg/sec (3 sigma) (x, y, z)	Drives sizing of RWs. Initial momentums determined by the LV	GN&C, LV	2.1.2 (Mission Life), 2.1.4.2 (LV Perf)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.2.2		**Pointing Knowledge**	The Observatory shall provide sufficient pointing knowledge both for enabling science observations and for orbit maintenance	N/A	N/A		1.3 (Ang Res & Coverage), 2.6.4 (Attitude Control)					
4.2.2.1				The Observatory shall provide pointing knowledge of 25 arcsec (3 sigma) with regard to the geocentric inertial frame in the X, Y and Z axes during science observation modes.	Need to understand the need for this requirement from the instrument team- currently no known rationale	GN&C, MECH, INSTR	??					
4.2.3		**Attitude Control and Stability**	The Spacecraft shall provide sufficient attitude control and stability to enable instrument science observations	N/A	N/A		1.3 (Ang Res & Coverage), 2.5.5 (Pointing & Jitter Control)					
4.2.3.1			The attitude control system shall provide a ground commanded capability to point to any point in inertial space.		Used not only to acquire sun pointing, but also for offpointing and calibration maneuvers	GN&C	1.5 (Precision), 2.6.4 (Attitude Control)					
4.2.3.2				The Spacecraft shall point the instrument science reference boresight (KCOR boresight, as designated in 2.5.5.1) to a target (nominally the center of the sun) to an accuracy 120 arcsec (3 sigma) with regard to the geocentric inertial frame in the X, Y, & Z axes over the period of the mission. Pointing requirement shall be met without the use of the GT.	Addresses the need for the Observatory to first allow the GT to acquire the sun to allow its utilization in Observatory pointing. 50 arcsec req derived from the GT linear range.	GN&C, SHARPP	1.3 (Ang Res & Coverage), 2.5.5 (Pointing & Jitter Control), 2.6.4 (Attitude Control)					
4.2.3.3				The attitude control system shall provide 2 arcsec (3 sigma) steady-state pointing accuracy (exclusive of jitter effects) relative to a GT error signal	Required to meet HMI 1 week pointing	GN&C	1.3 (Ang Res & Coverage), 2.5.5 (Pointing & Jitter Control), 2.6.4 (Attitude Control)					
4.2.3.4				The Spacecraft ACS shall be able to execute a 180 degree slew and settle to Observatory pointing accuracy (as indicated in 4.2.3.2) within a period of 20 minutes	Used to bound the accuracy and time period required for Observatory calibration maneuvers and setup for orbit adjust maneuvers. 20 minute req driven by worst case Geo burn offpointing and 90 min battery charge allocation (20 min initial slew, 40 min burn, 20 return slew). Excludes momentum stored as result of initial tipoff rates	GN&C	2.6.4 (Attitude Control)					
4.2.3.5				During science operations, the rotation of the Spacecraft YZ plane shall be maintained at a constant angle (within the accuracy requirements of 4.2.3.2) relative to the solar north pole	Addresses roll control requirement in relation to maintaining the Observatory X axis (instrument boresight) in the proper sun pointing orientation	GN&C	1.3 (Ang Res & Coverage), 2.6.4 (Attitude Control)					
4.2.4		**Propulsion & Delta-V**	The Spacecraft shall provide the capability for orbit insertion, orbit maintenance, and Observatory disposal	N/A	N/A		2.1 (Orbit), 2.4 (LV)					
4.2.4.1		Propulsion System	The Spacecraft shall implement an onboard propulsion system with sufficient propellant budget for all phases of the mission		Mission Phases referenced in 2.5.8	GN&C, PROP	2.1 (Orbit), 2.4 (LV)					
4.2.4.1.1			The thruster locations and orientations shall be selected to provide Delta-V functionality over the mass properties configuration throughout the mission life		Addresses the effect of changing CM over the mission life (due to fuel depletion) and the effect on thruster placement and effectiveness	GN&C, PROP, FLT DYN, MECH	4.1.2.2 (S/C CM vs Thruster placement)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.2.4.1.2			The detailed propellant budget shall be documented in the SDO Propulsion System Delta-V Budget Spreadsheet (doc # **TBD**)		Configured Delta-V budget spreadsheet covers all phases of mission operation and Observatory disposal in accordance with a five year mission life. Covers thruster calibration, tip-off correction, orbit circularization, periodic RW momentum unloading and on-station maneuvers, and Observatory disposal	GN&C, PROP, FLT DYN	4.2.4.1 (Delta-V)					
4.2.4.1.3			The Propulsion system shall include thruster & isolation valve inhibits for ground test and pre-launch operations		Prevents inadvertent firing of thrusters. Inhibits include arm/fire command sequence, ground safing procedures, as well as arm plugs which must be in place to fire thrusters (test plugs provide GSE simulation of thruster firing in ground testing in lieu of actual thruster valve actuation, allowing testing of thruster hardware and S/W). See 4.6.1.3 for related guidance	GN&C, PROP, GSE	2.2.2 (Fault Tol), 4.2.4.1 (Delta-V), 2.7.7 (Safety)					
4.2.4.1.4			The thruster catalyst bed heaters shall have proper thermal control protection in place to prevent inadvertent overheating during ground testing.		Prevents catalyst bed damage due to overheating outside vacuum environment. Protection includes ground safing procedures, catbed temperature monitoring and alerts. See 4.6.1.3 for related guidance	GN&C, PROP, THERM	2.2.2 (Fault Tol), 4.2.4.1 (Delta-V), 2.7.7 (Safety)					
4.2.4.2		Delta-V Maneuver Predictability	The execution of delta-V maneuvers shall be sufficiently predictable to achieve the required mission trajectory within the propellant allotment		Requirement reflects the fact that the predictability of the maneuver outcome affects the size of the delta-V maneuvers and the propellant required	GN&C, PROP, FLT DYN, GND	2.4 (LV), 2.4.2 (Delta-V)					
4.2.4.3		Notification	The Observatory shall provide notification to the instruments over the 1553 bus prior to any thruster operations		Any planned thruster operations will be included to the SOCs as part of mission planning notification. In preplanned thruster modes, the req implementation will provide some advance lead time prior to the action. This req also addresses unplanned emergency thruster firings and therefore in those cases will result in extremely short notification lead time. Allows instruments the opportunity to reconfigure in response to pending action	GND, FSW, C&DH	2.7.7 (Safety)					
4.2.5		**Momentum Management**	The Spacecraft shall be designed to provide the necessary momentum management for all phases of the Observatory lifetime	N/A	N/A		2.5.5 (Pointing & Jitter Control)					
4.2.5.1				The Spacecraft shall have the capability to use thrusters to remove residual angular momentum within 15 minutes after LV separation to within the rates specified by 4.2.1.3	Addresses the need to use ground commanded thrusters to reduce Observatory rates to a level within initial acquisition capability in case of higher initial LV induced rates.	GN&C, PROP	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control), 2.4.2.4 (LV Perf)					
4.2.5.2				The combined momentum unloading and stationkeeping maneuvers shall have a frequency of no more than once every 4 weeks	Defines analysis, accuracy, and predictability for Delta H and Delta V effects	GN&C, PROP, FLT DYN, GND	2.5.3 (Data Comp), 4.2.4 (Delta-V), 4.2.4.1.2 (Delta-V Budget)					
4.2.5.3				Pointing control for all on-station momentum maneuvers shall be within +/- 5 deg (TBR) (3-sigma) per axis	Bounds the perturbation of the nominal Observatory pointing during momentum unloading	GN&C, PROP	2.5.3 (Data Comp), 2.5.5 (Pointing & Jitter Control)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.2.6		**Safehold**	The Spacecraft design shall provide an autonomous mode used to maintain a power-safe, thermal-safe, and instrument-safe environment in the event of Observatory anomalies		Instrument safing provided prior to offpointing, load-shedding, etc when possible.	GN&C	2.2.2 (Fault Tol), 2.5.6 (Autonomy), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.1				The Spacecraft shall be designed to achieve an orientation placing the solar arrays within +/- 15 degrees normal to the sun from any initial orientation	Addresses need to remain power positive during safehold. Infers no requirement for rotation about the sun line while in S/H.	GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.2				The pointing attitude within the accuracy defined in 4.2.6.1 shall be attained within 30 minutes of entering this operational mode or exiting an eclipse period	Based on preliminary GN&C team estimate. Addresses limited battery life, drives RW sizing. Note that eclipse is estimated to be up to 70 minutes in duration (plus 30 minute sun acq safehold for worst case condition), affecting battery life reqs.	GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.3				The Spacecraft shall be designed with the capability to remain in safehold indefinitely with ground intervention	Addresses the autonomous nature of maintaining safehold operational mode. Implies RW momentum unloading (which requires ground commanding) in order to maintain required pointing after momentum buildup	GN&C, GND	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.4				The Spacecraft shall be designed to maintain safehold pointing without any ground intervention for a period of at least 7 days during GEO operations.	Addresses momentum management margin required as part of regular unloading period- need to plan unloading with sufficient margin to still maintain pointing if safehold entered immediately prior to regularly scheduled momentum unloading maneuver. Infers that Safehold pointing requirement is in addition to 4 week momentum unloading req in 4.2.5.2 (resulting in 5 weeks of momentum buildup)	GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.4.1				Maintain safehold pointing for >/- 2 orbits with no ground intervention during transfer orbit.		GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.5			Autonomous safehold operations should not be impeded by the loss of the central spacecraft flight processor or the 1553 spacecraft data bus and shall be altogether independent of these elements		Addresses the autonomous and independent performance aspects defined by safehold. Indicates SDO implementation decision that safehold shall be controlled by an independent processor and a path of safehold component control independent of the 1553 bus or similar shared data bus.	GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.2.6.6			The Observatory shall provide notification to the instruments over the 1553 bus when Safehold has been entered		Allows instruments the opportunity to reconfigure in response to action. Notification will probably be implemented as the non-transmission of S/C message (since 1553 bus may be disabled prior to entering S/H	GND, FSW, C&DH, GN&C	2.2.2 (Fault Tol), 2.6.3 (Power Dist), 2.6.4 (Attitude Control)					
4.3		**Power**		N/A	N/A							
4.3.1		**Power Generation**	Provide sufficient power generation to support the Observatory through all the phases of the mission	N/A	N/A	PWR	2.1 (Orbit), 2.2 (Mission Life), 2.6.3 (Standard S/C Services-Power)					
4.3.1.1				The power system shall have the capability to support 1325 W (TBR) orbital average power load at the end of the 5 year mission life for the geosynchronous orbit selected		PWR	2.1 (Orbit), 2.2 (Mission Life), 2.6.3 (Standard S/C Services-Power)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.3.2		**Power Storage**	Provide sufficient energy storage to support the Observatory through all the phases of the mission	N/A	N/A							
4.3.2.1				The battery shall not exceed a total of 550 cycles of 60% depth of discharge as part of qualification and acceptance testing, pre-launch testing and mission ops.	Provides protection against Li-Ion battery degradation through large number of deep discharge cycles	PWR	2.1 (Orbit), 2.2 (Mission Life), 2.6.3 (Standard S/C Services-Power)					
4.3.2.2				100 battery cycles shall be allocated to pre-launch and acceptance testing, with the remaining cycles reserved for flight accommodation	Addresses the number of battery cycles in 4.3.2.1 allocated for ground operations							
4.3.2.3				The battery shall be able to provide at least 600 watts (TBR) for 90 minutes (TBR) as part of the launch phase in order to allow the Observatory to acquire power positive orientation after launch	Defined by launch worst case assumptions- include 15 minute internal power hold prior to launch, 30 minutes post launch prior to separation, 15 minutes to unload momentum with use of thrusters, and 30 minutes to achieve safehold pointing (90 minutes)	PWR	2.1 (Orbit), 2.2 (Mission Life), 2.6.3 (Standard S/C Services-Power)					
4.3.2.4				The battery shall be able to provide at least TBD (1325 W) for 72 minutes at EOL to support worst case eclipse condition without load shedding instruments	Addresses worst case eclipse conditions	PWR	2.2 (Mission Life), 2.5.3 (Data Comp), 2.6.3 (Standard S/C Services-Power)					
4.3.2.5				The battery shall be able to provide power for Spacecraft operations for 102 minutes at EOL to support worst case eclipse conditions. In order to meet this requirement, load shedding is permitted	Defined by the worst-case eclipse duration (72 minutes), worst case safehold acquisition (30 minutes) plus margin. Note that instruments will be powered at this time and may need to be load-shed if necessary.	PWR	2.2 (Mission Life), 2.6.3 (Standard S/C Services- Power)					
4.3.3		**Power Distribution**	The Spacecraft design shall provide the capability for power distribution within the Observatory									
4.3.3.1				The output of the power subsystem shall provide for the distribution 29V +/- 6V power to all Observatory electronic subsystems and components.	Defined by power regulation specification of power subsystem.	PWR	2.6.3 (Standard S/C Services-Power)					
4.3.3.2				All electronic subsystems shall be qualified to a voltage bus range of 22-35 V	Difference between 4.3.3.1 assumes a 1 volt drop between PSE output and component input	Electrical Subsystems	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power)					
4.3.3.3			The spacecraft power system shall utilize a distributed power architecture with primary high-current power distributed to the Observatory subsystems for further distribution as needed		Higher power components may receive power directly from PSE due to current draw considerations	PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), SDO Arch. Design					
4.3.3.4			The power subsystem shall provide dual power feeds to all components as part of the operational and survival distribution, with appropriate power isolation design incorporated in the event of power distribution faults		Reflects redundancy and reliability requirements need to meet mission life	PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power)					
4.3.3.5			Unswitched power services shall be appropriately fused to prevent damage to or loss of the Spacecraft power system due to excess current draw. Switched services shall have remotely resetable "circuit breaker" for power system protection.		Safety and reliability design implementation in support of redundant spacecraft design. "Circuit breaker" function resettable by ground command	PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), 2.7.7 (Safety)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.3.3.6				The power subsystem shall provide the capability for a minimum of 24 (TBR) Observatory-controlled switched and 6 (TBR) unswitched high power services on both the primary and redundant power output modules to meet Observatory requirements.	Based on initial power services assessment. Implementation detailed in power distribution diagram	PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), SDO Arch. Design					
4.3.3.7				All Electronic components shall be designed with redundant power inputs with diode protection on each line		Electrical Subsystems	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), SDO Arch. Design					
4.3.3.8			The GSFC in-house subsystems/components shall use a common power design implementation consisting of a processor-controlled secondary power distribution system for lower power switched services, based on a common dc-dc converter/power switching design implementation		Requirement reflects project design decision to utilize common distributed processor-controller power system design; offers advantages in design commonality along with associated benefits in testability, reliability, cost and manpower reduction	PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), SDO Arch. Design					
4.3.3.9				In addition to the primary and redundant power services, the Spacecraft power system shall provide TBD (3??) switched CCD decontamination heater service(s) to the SDO instruments	Provides Observatory-controlled switched service to prevent contamination deposits on instrument detectors during instrument powered-off conditions in post-launch and survival modes, as well as opportunity to perform on-flight CCD decontamination as necessary. Still need to work out the details of Observatory vs Instrument in-flight heater control and total number of services provided	PWR, INSTR	1.5 (Precision), 2.1.2 (Mission Life), 2.3.3 (Contam)					
4.3.4		**Load Shedding**	The Observatory shall be designed with the capability to execute a pre-determined hierarchy of load shedding operations based on power system status telemetry. This capability shall be independent of the spacecraft central processor and the 1553 bus			PWR	2.2.2 (Fault Tol), 2.6.3 (Standard S/C Services-Power), SDO Arch. Design					
4.3.5		**Constraints**	Appropriate limits will be provided to avoid exceeding peak discharge rates on the battery	N/A	N/A							
4.3.5.1				The torque commanded to each reaction wheel assembly shall be software-limited such that the maximum power draw per wheel shall not exceed 300 watts/sec (TBR).	Prevents RW current draw from exceeding Power subsystem output module specifications. Is there an additional requirement for power-saving power limitations during initial post-launch sun acquisition to limit power drain on battery prior to power-positive operations?	GN&C, FSW, PWR	2.6.3 (Standard S/C Services-Power)					
4.3.5.2				Simultaneous thruster firings shall be limited to the combinations of either one 110lb engine and four 5lb thrusters or eight 5lb thrusters in order to limit the maximum instantaneous power draw	Assumes 5 lb thrusters with ~ 10-15 W draw each and 25 lbs thrusters with ~ 25 W draw each	PWR, GN&C, FSW, PROP	2.6.3 (Standard S/C Services-Power)					
4.3.5.3			All components shall design to appropriate in-rush current requirements as defined in the SDO Electrical System Specification (doc # TBD)		Prevents power-on transients that could damage or loss to Observatory power system or subsystem components	PWR, ELEC, Electrical Subsystems	2.7.4 (Elec)					
4.4		**Comm & Data System**	N/A	N/A	N/A		2.6.5 (Standard S/C Services-Comm)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.1		**S-Band Communications**	N/A	N/A	N/A							
4.4.1.1		Uplink	A forward command link shall be provided to support Observatory commanding	N/A	N/A	GND, RF, C&DH	2.6.5 (Standard S/C Services-Comm)					
4.4.1.1.1			The command uplink shall be compatible with the SDO ground system, TDRSS, DSN and USN networks. This requirement can be met using the GSTDN format.		Addresses the potential need for multiple ground station networks either for nominal ops or potential contingency operations	GND, RF, C&DH	2.6.5 (Standard S/C Services-Comm), 2.5.1 (Continuous Contact), 2.2.2 (Fault Tol)					
4.4.1.1.2			The command link shall utilize the CCSDS command path service protocol; both COP-1 and bypass modes shall be supported			GND, RF, C&DH, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.1.1.3			Full spherical command link coverage shall be supported through all mission phases		Defines the use of dual omni antennas for spherical coverage.	GND, RF, C&DH	2.6.5 (Standard S/C Services-Comm)					
4.4.1.1.4				The mission shall support an uplink command rate of up to 2 Kbps		GND, RF, C&DH, FSW	2.6.5 (Standard S/C Services-Comm)					
4.4.1.1.5			The uplink bit error rate and command checking shall be such to preclude the execution of an invalid command		Implies bit error rate, link margin, command verification, and command retransmission to maintain a robust command link	GND, RF, C&DH	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.1.1.6				The S-Band command uplink shall have a link margin of ≥ **TBD** dB through all mission phases	Margin helps ensure a stable and reliable RF uplink communications path	GND, RF	2.6.5 (Standard S/C Services-Comm)					
4.4.1.1.7			The uplink command path shall include appropriate security measures to prevent the execution of any unauthorized command sequences		Reflects the need for Observatory security measures (need to reference specific NASA requirement here)	GND, C&DH, FSW	2.6.5 (Standard S/C Services-Comm), NASA Security Guidance					
4.4.1.1.8				Each uplink receiver shall receive unswitched power from the power system and shall not have the capability to be powered off	Reflects robust spacecraft design requirement to maintain command receive capability at the Observatory at all times	C&DH, PWR	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.1.2		Downlink	A return link shall be provided to support Observatory housekeeping telemetry transfer to the ground station	N/A	N/A	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.1			The downlink shall be compatible with the SDO ground system, TDRSS, DSN and USN networks. This requirement can be met using the GSTDN format.		Addresses the potential need for multiple ground station networks either for nominal ops or potential contingency operations	GND, RF, C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.2				The housekeeping downlink telemetry shall support the CCSDS AOS protocol	The SDO baseline is CCSDS protocol	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.3				Housekeeping telemetry shall comply with the CCSDS AOS Grade 2 service		GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.4				The S-Band downlink shall have a link margin of ≥ 3 dB through all mission phases	Margin helps ensure a stable and reliable RF downlink communications path	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.5			The downlink rate shall support the simultaneous downlink of both real time and stored housekeeping data through all mission phases			GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.1.2.6				The downlink shall have the capability to allow recovery of 24 hours of stored housekeeping data while simultaneously downlinking real-time data to the ground station	Implies the need for acceptable bit error rates, SSR EDAC, data retransmission, and recorder management such that Observatory data is not released until valid data receipt on the ground is confirmed	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem), 2.2.2 (Fault Tol)					
4.4.1.2.7				The downlink rate and mission design shall support the simultaneous downlink of real-time housekeeping and 24 hours of stored housekeeping data at Geo within 60 minutes (TBR)	Propose time duration to be 30-60 minutes; determines the maximum rate required for what is expected to be worst case housekeeping DL req; implies the use of serial bus to dump SSR due to 1553 bus bandwidth limitations. Will likely require scheduled ground pass with larger antenna in order to meet DL rate requirement	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.8				The Downlink shall support a minimum downlink data rate of 1 Kbps (TBR) and a maximum downlink data rate of 500 Kbps (TBR)	Bounds DL rate requirements. Minimum rate driven by TDRSS emergency mode and network compatibility testing. Maximum rate derived from worst case of 4.4.1.2.6	GND, RF, C&DH	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.1.2.9				The downlink hardware shall provide the capability to latch and record the Vc0 frame sync time with TBD accuracy when it is transmitted in the downlink data stream and transmit this time to the ground	Reflects the need for Vc0 frame sync time for Vc0 Range Data Delay (RDD) spacecraft/ground time correlation method	C&DH	4.4.3.8 (Time), 5.2.5 (Tracking)					
4.4.1.2.9			The Observatory transponder shall support turnaround ranging		Required for orbit determination and prediction	RF	5.2.5 (Tracking)					
4.4.1.2.10				The Observatory transponder shall support simultaneous telemetry and turnaround ranging on the RF downlink by utilizing a carrier and subcarrier to provide separate channels for each. The transponder shall also have the capability to disable the subcarrier and directly modulate the downlink carrier with telemetry	This requirement is driven by the need to allow long tracking data arcs to be captured following GTO manuevers while still maintaining S/C telemetry. Note that the req to disable the subcarrier is designed to maximize data rates for recorder dumps when ranging is not required. See 5.2.1.5 and 5.2.2.5 for ground system reqs	C&DH, RF	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem), 5.2.5 (Tracking)					
4.4.1.2.11			The Downlink shall have the capability to operate both in coherent and non-coherent modes		Non-coherent- DL freq based on XPNDR internal oscillator freq (fixed); Coherent- DL freq based on uplink freq modulation (variable)- needed for ranging	RF	5.2.5 (Tracking)					
4.4.2		**Ka-Band Communications**	A return link shall be provided to support Science telemetry transfer to the ground station				1.6 (Cadence), 2.5.3 (Data Capture & Compl), 2.6.5 (Standard S/C Services- Comm)					
4.4.2.1				The science telemetry shall support the CCSDS protocol recommendations		C&DH, GND	2.6.5 (Standard S/C Services- Comm)					
4.4.2.2				The downlink rate shall support the continuous 150 Mbps downlink of science data (300 Mbps symbol rate w/ Conv encoding) while on station in a geosynchronous orbit	Reflects science data rate of 130 Mbps plus overhead and downlink encoding (130 + headers + RS + Conv = ~ 300 Mbps)	C&DH, RF, GND	1.6 (Cadence), 2.5.3 (Data Capture & Compl), 2.6.5 (Standard S/C Services- Comm)					
4.4.2.3				The downlink bit error rate shall be less than 1x10-8 (including downlink encoding benefits)	Reflects the preliminary calculation of the DL portion of the 99.99% data science data completeness budget requirement; Reflects error rate of data recovered after transmission and recovery at ground station	C&DH, RF, GND	1.6 (Cadence), 2.5.3 (Data Capture & Compl), 2.6.5 (Standard S/C Services- Comm)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.2.4				Ka-Band link calculations shall include the assumption of 99.25% availability due to atmospheric and rain attenuation	Reflects data capture budget assumption of only 66 hours lost due to rain attenuation [1 - 66 hours/(24 hrs/day* 365 days/year)= 0.9925]	C&DH, RF, GND	1.6 (Cadence), 2.5.3 (Data Capture & Compl), 2.6.5 (Standard S/C Services-Comm)					
4.4.2.5				The Ka-Band Science downlink shall have a link margin of ≥ 3 dB	Margin helps ensure a stable and reliable RF downlink communications path	RF, GND	1.6 (Cadence), 2.5.3 (Data Capture & Compl), 2.6.5 (Standard S/C Services-Comm)					
4.4.2.6				Deleted								
4.4.3		**Data System Functions**										
4.4.3.1		Architecture	The Spacecraft shall employ the use of a distributed processing architecture with a central spacecraft processor and subsystem common nodal processing elements for commanding and telemetry collection using the same core design and layout		Requirement reflects project design decision to utilize common distributed processor-controller power system design; offers advantages in design commonality along with associated benefits in testability, reliability, cost and manpower reduction	C&DH, GN&C, PWR, APS, FSW	2.1.2.2 (Fault Tol), 2.6.6 (Standard S/C Services- Data processing), SDO Arch. Design					
4.4.3.2		Attitude Control Processing	The Spacecraft shall support the attitude control system processing requirements		ACS Single Board Computer requirements encompassed in S/W SBC reqs provided to C&DH	C&DH, GN&C, FSW	2.6.6 (Standard S/C Services-Data processing)					
4.4.3.2.1				The data system and 1553 bus shall provide sufficient capability to support a 5 Hz closed loop control capability for Observatory attitude control	Requirement based on instrument pointing requirements	C&DH, GN&C, FSW	2.6.6 (Standard S/C Services-Data processing), 4.2.3 (Control & Stability)					
4.4.3.2.2				The maximum allowable delay in the closed loop attitude control is one ACS closed loop control cycle as defined in 4.4.3.2.1.	Derived from 5 Hz loop requirement and pointing requirement. This value is typically what is assumed for S/C controller stability & robustness	C&DH, GN&C, FSW	2.6.6 (Standard S/C Services-Data processing), 4.2.3 (Control & Stability)					
4.4.3.3		Memory Management	The Observatory shall provide memory management functions									
4.4.3.3.1			All on-board processors shall provide the capability to load code and data from the ground to on-board processors		Requirement allows flexibility to adjust for on-orbit conditions	C&DH, GN&C, PWR, INSTR, FSW	2.6.6 (Standard S/C Services-Data processing)					
4.4.3.3.2			The Spacecraft central processor shall provide the capability to load code and data from the ground to into non-volatile memory		Reflects the need to retain updated data and code despite resets and power cycling	C&DH, FSW	2.6.6 (Standard S/C Services-Data processing)					
4.4.3.3.3			The Observatory shall provide the capability to dump onboard processor memory to the ground station			C&DH, FSW	2.6.6 (Standard S/C Services-Data processing), 2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.3.4			All on-board processors shall have adequate memory protection against memory errors		Memory errors may be induced by radiation effects or hardware failures (stuck bits). S/C processor may elect to utilize checksumming of static memory to detect, correct and report bit flips, while other processors may utilize rad hard memory and memory management	C&DH, GN&C, PWR, INSTR, FSW	2.1.2.2 (Fault Tol), 2.6.6 (Standard S/C Services- Data processing)					
4.4.3.4		Commands										

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.3.4.1		Real Time Commands	The Spacecraft shall provide a capability to receive, decode, validate and distribute real time commands			C&DH, RF, FSW	2.6.5 (Standard S/C Services-Comm)					
4.4.3.4.1.1				The Observatory shall use the 1553 bus to distribute commands to the relevant Observatory subsystems		C&DH, RF, FSW	2.6.5 (Standard S/C Services-Comm)					
4.4.3.4.1.2				The uplink command decode function shall receive unswitched power from the power subsystem and shall not have the capability to be powered off		C&DH, RF	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.2		Hardware Decoded Commands	The Spacecraft shall provide a capability to support hardware decoded commands, which are received, decoded, and distributed by the Observatory hardware without the intervention of flight software			C&DH, RF	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.2.1				The uplink hardware shall have the capability to decode and distribute a minimum of 16 (TBR) hardware decoded commands to Observatory subsystems	Required to reset, recover and reconfigure the Observatory in the absence of processor or flight software operation. Specific # of cmds will be determined by reconfiguration needs of the observatory. Explore the possible use of limited H/W cmds and more SDN S/W cmds	C&DH, RF	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.3		Stored Commands	The Spacecraft shall provide a stored command capability to receive, store, and later execute sequences of commands			C&DH, RF, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.3.1				The Spacecraft shall provide at least two absolute time stored command sequence buffers with a relative accuracy of 1 second command execution	Use of two or more buffers allows capability to load one buffer whith utilizing the other	C&DH, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.3.2				The Spacecraft shall provide relative time stored command sequences with a relative accuracy of 1 second command execution		C&DH, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.4.3.3				The Spacecraft shall provide a capability to initiate relative time sequence commands triggered on telemetry events	Requirement supports using stored telemetry commands for health and safety functions	C&DH, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.5		Health and Safety		The Spacecraft shall provide for Telemetry Statistic Monitor (TSM) on-board telemetry monitoring points	Allows the use of TSM/RTS capability for the autonomous initiation of relative time command sequences upon detection of a pre-specified set of conditions	C&DH, FSW	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.6		Housekeeping Telemetry	The Observatory shall provide the capability to collect and downlink housekeeping telemetry through all phases of the mission			C&DH, RF, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.1			The data system shall provide error encoding to meet downlink data error rate requirements			C&DH, RF, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem), 2.2.2 (Fault Tol)					
4.4.3.6.2		Real time Telemetry	The Spacecraft shall collect and transmit Observatory housekeeping telemetry to the ground station in (near) real time.		Corresponding Ground System requirement is 5.2.4.1	C&DH, RF, FSW	2.1.5.5 (H/K Telem)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.3.6.3		Stored Telemetry	The Spacecraft shall collect and store Observatory housekeeping telemetry for later transmission to the ground station			C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.1				The Spacecraft shall have the capability to store and dump up to 24 hours of housekeeping telemetry in nominal mission mode	Required for dump and evaluation of on-board anomalies where loss of telemetry occurs; Recorder size restrictions may drive telemetry sampling rate	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.2				The spacecraft shall provide 90 Mbytes (TBR) spacecraft recorder for storage of housekeeping telemetry through all phases of mission operations	Recorder size defined by ops concept and bounded by largest storage requirements in either launch and IOC, GTO circularization, or 24 storage during Observatory on-station anomalies. Initial assumption of 8 Kb/sec rate for 24 hours, resulting in 86.4 Kbyte recorder	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.3				The Spacecraft shall have the capability to record telemetry at a sampling rate of up to 32kb/sec for shorter intervals where higher sampling rates are required	24 hour storage requirement does not apply to higher telemetry sampling rate	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.4				The data system recorder shall have a bit error rate of less than 1x10-9 (TBR)	Drives need for recorder error scrubbing. Initial recorder error rate based on roughly equivalent error rate (per bit) at science data	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.5			The Spacecraft shall have the capability to playback stored telemetry to the ground station upon command			C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.6			The Spacecraft shall support the simultaneous downlink of both real time and stored housekeeping data through all mission phases			C&DH, RF, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.7				The Spacecraft shall support the capability to collect and store housekeeping telemetry while playing back stored telemetry to the ground station	Allows a running buffer to be kept of housekeeping telemetry in the event of an anomaly during playback	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.6.3.8				The Housekeeping telemetry collection/storage rate and content shall be reconfigurable via ground command	Implies the use of Filter Tables to set collection/record/playback parameters through the various phases of mission operations	C&DH, FSW	2.6.5, 2.6.7 (Standard S/C Services- Comm & H/K Telem)					
4.4.3.7		Science Data	The Observatory shall route science data for downlink transmission to the ground station		The corresponding Ground System requirement is 5.2.5.1	INSTR, C&DH	2.6.5 (Standard S/C Services- Comm)					
4.4.3.7.1			The Observatory shall collect continuous fixed-length instrument science data frames via the IEEE 1355 interface protocol and provide encoding for continuous transmission to the science ground station		Reflects science data DL requirements and lack of instrument science data storage; Ongoing discussion on whether Instruments provide complete VCDUs or simply fixed length frames	INSTR, C&DH	1.6 (Cadence), 2.6.5 (Standard S/C Services- Comm)					
4.4.3.7.2				The spacecraft onboard science data bit error rate shall be less than $1x10^{-10}$ and applies to the data path from the instrument CCD output to the conversion to RF signal	Reflects the spacecraft hardware portion of the 99.99% science data completeness budget requirement. Worst case assumption is that single bit flip results in packet frame loss- can support up to TBD packet frame losses per day and meet data completeness req. Implies use of significant rad hard components to meet this req.	INSTR, C&DH	1.2.2 (Data Compl)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.4.3.7.3			The science data downlink shall provide forward error correction encoding to meet downlink data error rate requirements			C&DH	2.6.5 (Standard S/C Services-Comm), 1.2.2 (Data Compl)					
4.4.3.7.4				The maximum science observation data transferred to the S/C for encoding and downlink to the ground station shall not exceed an aggregate total of 130 Mbps (150 Mbps downlink once error encoding and margin added)	Places upper limit on Science data rate based on Instrument collection and data rate allocations. 130 Mbps includes science data packet headers	C&DH	1.6 (Cadence), 2.6.5 (Standard S/C Services-Comm)					
4.4.3.7.5			The Science data downlink function shall have the flow-control capability of limiting the data from each instrument input to its allocated data rate		Capability prevents data from one instrument from inadvertently flooding the downlink data stream and interfering with the data downlink from other instruments	C&DH	2.6.5 (Standard S/C Services-Comm), 1.2.2 (Data Compl)					
4.4.3.7.6			The science data flow control capability shall be reconfigurable in flight to allow reallocation of instrument science data telemetry bandwidth		Allows reconfiguration for optimal use of B/W	C&DH	2.6.5 (Standard S/C Services-Comm), 2.2.2 (Fault Tol)					
4.4.3.7.7			The science data downlink function shall assure that the data from each instrument source is uniquely identified		Implies that the DL function inserts virtual channel frame headers or verifies that the virtual channel ID in each fixed frame is correct. This allows correct science data routing on the ground via science frame headers	C&DH	2.5.4 (Data Delivery)					
4.4.3.8		Time Implementation	The Observatory shall maintain time to the accuracy required by all aspects of the mission				2.6.6 (Timing)					
4.4.3.8.1		Relative Time Accuracy		The Spacecraft shall maintain time and make it available to components over the 1553 bus with a relative accuracy of 10 ms (TBR) over a period of 1 sec	Reflects preliminary implementation decision to use 1553 bus as time distribution approach- need to investigate relative time accuracy that can be achieved using this approach and verify relative accuracy	C&DH, FSW	2.6.6 (Timing), 4.2 (Attitude Cntrl & Det), 4.4.3.4.3 (Stored Cmds)					
4.4.3.8.2		Absolute Time Accuracy	The mission shall support the ability to adjust and maintain the Observatory time clock to compensate for onboard time drift and stability effects			C&DH, FSW, GND	2.6.6 (Timing), 4.2 (Attitude Cntrl & Det), 4.4.3.4.3 (Stored Cmds)					
4.4.3.8.2.1				The mission shall support the ability to maintain Observatory time to ground time to within 100 msec (TBR)	Based on HMI requirement of 100 msec (with goal of 10 msec) which appears to be more stringent than (and therefore encapsulate) the other instrument reqs. Planning on using Vc0 time correlation approach. In order to meet this req, need to measure to ~ 10 ms and use to predict and adjust time drift.	C&DH, FSW, GND	3.2.4 (HMI timing), 2.6.6 (Timing)					
4.4.3.8.2.2			The Spacecraft shall provide a "smooth" time adjust capability to allow instrument time to be updated without time jumps or discontinuities			C&DH, FSW, INSTR, GND	3.2.4 (HMI timing), 2.6.6 (Timing)					
4.4.3.8.2.3				During science operations, the maximum time adjust shall be no greater than 100 µsec (TBR) over a period of 1 sec (TBR)		C&DH, FSW, INSTR, GND	3.2.4 (HMI timing), 2.6.6 (Timing)					
4.5		**High Gain Antenna (HGA) Assembly**	**The Spacecraft shall provide a HGA function that meets the science downlink rate and reliability requirements of the mission**				1.6 (Cadence), 2.5.1 (Cont. Contact), 2.5.3 (Data Capture & Compl)					
4.5.1		**Operation, Pointing and Stability**										

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.5.1.1			The HGAs implementation shall provide sufficient FOV coverage in the nominal mode of operation such that Observatory attitude adjustments are not needed for full antenna ground station coverage			APS, RF, DEPLOY	1.2 (Data Capture & Compl), 2.1.5.3 (Data Comp Budget), 2.2.2 (Fault Tol)					
4.5.1.2			Deleted									
4.5.1.3				The HGA implementation shall provide a pointing accuracy of +/- 0.25 deg to the ground station	This requirement may actually need to be broken out into three separate reqs: ACS knowledge, deployment repeatability/knowledge, and HGA gimbal pointing accuracy. The 0.25 deg offset angle corresponds to a 0.25 dB gain reduction for 1/2 meter HGA dish. Budget does not include DC error components that can be statically removed	APS, RF, DEPLOY, GN&C	1.2 (Data Capture & Compl), 2.1.5.3 (Data Comp Budget)					
4.5.1.4				The contribution of HGA operation to nominal Observatory attitude control disturbance effects shall not exceed 0.5 arcsec (TBR)	Initial HGA ROM indicated < 0.1 arcsec contribution per gimbal- further investigation needed	APS	4.2.2 (Pointing Acc), 4.2.3 (Attitude Cntrl & Stability)					
4.5.1.5				The HGA implementation shall be able to calibrate out antenna deployment errors of up to +/- 1 deg (TBR)		GND, DEPLOY, APS, RF	4.2.2 (Pointing Acc), 4.2.3 (Attitude Cntrl & Stability)					
4.6		**Deployment Actuation and Verification**	The Spacecraft shall support the capability to initiate and monitor solar array and High Gain Assembly (HGA) deployment functions	N/A	N/A							
4.6.1		**Solar Array Deployment and Verification**		The Spacecraft shall provide a nominal deployment capability based of receipt of 2/3 of the LV/Observatory separation signals	Baseline deployment option utilizes processor/software control to detect separation and initiate deployment and confirmation	PWR, DEPLOY, FSW	2.6.3 (Standard S/C Services-Power), 2.4.3.3 (Sep Sigs)					
4.6.1.1				The Spacecraft shall provide an independent hardware capability to autonomously deploy the solar arrays upon positive receipt of 3/3 separation signals between the LV/Observatory	Reflects the need for independent deployment of solar arrays in the event of processor or Software anomaly	PWR, DEPLOY	2.6.3 (Standard S/C Services-Power), 2.4.3.3 (Sep Sigs), 2.2.2 (Fault Tol)					
4.6.1.2			The Spacecraft shall provide a ground-based deployment command initiation capability		Allows independent deploy command capability independent of separation signal control	PWR	2.6.3 (Standard S/C Services-Power), 2.4.3.3 (Sep Sigs), 2.2.2 (Fault Tol)					
4.6.1.3			The Spacecraft shall provide sufficient deployment blocks/interrupts to prevent inadvertent deployment initiation during ground testing		Reflects ground test safety needs to prevent inadvertent deployment	PWR, GSE	2.6.3 (Standard S/C Services-Power), 2.4.3.3 (Sep Sigs), 2.2.2 (Fault Tol), 2.7.7 (Safety)					
4.6.1.4			The Spacecraft shall implement a redundant deployment function such that no reconfiguration of the Observatory is required to initiate deployment in the event of a failed deployment attempt		Reflects the design need to place back-up deployment functions within subsystem components powered and command-accessible as part of the nominal launch configuration; eliminates the need to first reconfigure Observatory in the event of an unsuccessful deployment attempt, further risking Observatory survival. Also implies need for redundant deployment mechanism	PWR, DEPLOY	2.6.3 (Standard S/C Services-Power), 2.4.3.3 (Sep Sigs), 2.2.2 (Fault Tol)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
4.6.1.5			The Spacecraft shall provide the capability to detect and monitor solar array deployment as part of the deployment verification process			PWR	2.5.7 (Critical Telem monitoring))					
4.6.1.6			The Spacecraft shall block the power-on and initiation of reaction wheel operation until on-board telemetry confirms the positive deployment of Observatory solar arrays; this capability will have an override feature to allow ground override of this blocking approach		Reflects dual implementation needs; the need to prevent initial safehold acquisition until positive separation to prevent RW damage due to attached third stage; the need for an emergency RW safing capability for ground testing	PWR, GN&C, FSW	2.6.3 (Standard S/C Services-Power), 2.7.7 (Safety)					
4.6.2		**High Gain Antenna (HGA) Deployment and Verification**	N/A	N/A	N/A							
4.6.2.1			The Spacecraft shall provide the capability for commanded deployment of the HGA		HGA deployment is not required immediately after separation and therefore is not an autonomous function	APS, DEPLOY, FSW	1.6 (Cadence), 2.5.1 (Continuous Contact)					
4.6.2.2			The Spacecraft shall implement a redundant commanded HGA deployment function such that no reconfiguration of the Spacecraft is required to initiate deployment in the event of a failed deployment attempt		Reflects the design need to place back-up deployment functions within subsystem components powered and command-accessible as part of the nominal deployment configuration; eliminates the need to first reconfigure Observatory in the event of an unsuccessful deployment attempt	APS, DEPLOY, FSW	1.6 (Cadence), 2.5.1 (Continuous Contact), 2.1.2.2 (Fault Tol)					
4.6.2.3			The Spacecraft shall provide the capability to detect and monitor HGA deployment as part of the deployment verification process			APS, DEPLOY, FSW	2.5.7 (Critical Telem monitoring))					
4.6.2.4				The Spacecraft shall provide the capability to deploy the HGA and verify HGA deployment angle to an accuracy of TBD (1 deg??)	Assume that HGA deploy angles can be calibrated out in orbit (see 4.5.1.5)	APS, DEPLOY	1.6 (Cadence), 2.5.1 (Continuous Contact),2.5.7 (Critical Telem monitoring))					
5		**Ground Segment Requirements**										
5.1		**Integration and Test (I&T)**	N/A	N/A	N/A							
5.1.1		**High Rate Science GSE**	The high rate science GSE shall have the capability to support testing and evaluation of the Observatory operation and instrument telemetry as part of ground testing			GND, GSE, C&DH	2.7.2 (Verif)					
5.1.1.1				The ground system high rate GSE shall capture and decode science data telemetry in real time		GND, GSE, C&DH	2.7.2 (Verif)					
5.1.1.2				The ground system high rate GSE shall deliver decoded science data to instrument test equipment in real time		GND, GSE, C&DH	2.7.2 (Verif)					
5.1.1.3				The ground system high rate GSE shall have the capability to record TBD hours of encoded and/or unencoded high rate data	Provides capability to record and playback science data from local ground station in addition to instrument SOCs	GND, GSE, C&DH	2.7.2 (Verif)					
5.1.2		**Low Rate GSE**	The Observatory GSE shall have the capability to decode, deliver, and display Observatory housekeeping telemetry in real time through all phases of ground testing and mission operation			GND, GSE, C&DH	2.6.7 (Standard S/C Services), 2.7.2 (Verif)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
5.1.2.1			The observatory GSE shall have the capability to format and send commands to the Observatory through all phases of ground testing and mission operation			GND, GSE, C&DH	2.6.7 (Standard S/C Services), 2.7.2 (Verif)					
5.2		**Ground Station Implementation**	**The Ground Station implementation and operation shall support SDO mission implementation and operation requirements through all phases of mission life**	N/A	N/A	GND	1.2 (Data Capture & Compl), 1.6 (Cadence), 2.5 (Ops Concept)					
5.2.1		**Dedicated Site Requirements**	The ground station sites shall meet the housekeeping and science data capture and loss budget requirements		Reflects need to locate site in area that meets atmospheric attenuation and FOV coverage requirements defined in the capture budget to meet the 95% science data requirement	GND	1.2 (Data Capture & Compl), 1.6 (Cadence), 2.5 (Ops Concept)					
5.2.1.1			The ground segment shall provide sufficient redundancy to meet the ground station data capture budget requirements		Addressed by implementation decision to use dual antenna and ground sites to meet data capture budget requirements	GND	1.2 (Data Capture & Compl), 1.6 (Cadence), 2.5 (Ops Concept), 2.2.2 (Fault Tol)					
5.2.1.2			Each ground station shall provide S-Band frequency command, telemetry and tracking functions in support of SDO mission operations			GND	2.5 (Ops Concept)					
5.2.1.3			Each ground station shall provide local Ka-Band frequency telemetry storage in support of SDO science operations		Required to handle temporary line outages between antennas and DDC	GND	1.2 (Data Capture & Compl), 1.6 (Cadence), 2.5 (Ops Concept)					
5.2.1.4			Ground station functions shall be capable of remote reconfiguration from the MOC		Allows MOC to modify Ground station as needed to support mission operations	GND	2.5 (Ops Concept)					
5.2.1.5				The Ground station shall be able to generate range tones on the uplink and receive simultaneous S-Band telemetry and ranging data modulated on an RF downlink subcarrier and carrier respectively. The station must be able to receive telemetry on either the carrier or subcarrier	Required for tracking capability. See 4.4.1.2.10 for S/C req	GND	2.5 (Ops Concept)					
5.2.1.6			End-to-end compatibility testing shall be conducted to verify the compatibility of all ground stations and any RF networks utilized with the Observatory and launch vehicle			GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry), 2.7.2 (Verification)					
5.2.2		**Ancillary Site Requirements**	The mission shall demonstrate verified compatibility with other NASA and/or commercial ground stations required during launch, early mission phases, and contingency support	N/A	N/A	GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry)					
5.2.2.1				All ancillary ground sites shall only be required to support the Observatory at the S-Band frequency and functions (command, telemetry, tracking for orbit determination)		GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry)					
5.2.2.2				All commands routed through the ancillary S-band ground sites shall originate from the SDO MOC for uplink to the Observatory	Requirement does not preclude SOC commanding, but requires commands to pass through MOC for checking and forwarding to the Observatory	GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry)					
5.2.2.3				All Observatory housekeeping telemetry collected by the ancillary S-band ground sites shall be forwarded in near real-time to the SDO MOC for archive and distribution to the respective SOCs		GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
5.2.2.4				End-to-end compatibility testing shall be conducted to verify the compatibility of all ground stations and any RF networks utilized with the Observatory and launch vehicle		GND	2.5 (Ops Concept), 2.5.7 (Critical Telemetry), 2.7.2 (Verification)					
5.2.2.5				The Ground station shall be able to generate range tones on the uplink and receive simultaneous S-Band telemetry and ranging data modulated on an RF downlink subcarrier and carrier respectively. The station must be able to receive telemetry on either the carrier or subcarrier	Required for tracking capability. See 4.4.1.2.10 for S/C req	GND	2.5 (Ops Concept)					
5.2.3		**Commanding**										
5.2.3.1				The ground station shall support a maximum S-Band command uplink data rate of 2 Kbps		GND	2.5 (Ops Concept), 2.6.5 (Standard S/C Services-Comm)					
5.2.4		**Housekeeping Telemetry**		N/A	N/A							
5.2.4.1			The ground station shall collect observatory housekeeping data in the S-Band frequency and distribute in real-time to the MOC			GND	2.5 (Ops Concept), 2.6.5 (Standard S/C Services-Comm)					
5.2.4.2				The ground station shall support a maximum housekeeping downlink data rate of **TBD** Kbps		GND	2.5 (Ops Concept), 2.6.5 (Standard S/C Services-Comm)					
5.2.4.3				The ground station shall have the capability to latch and record the Vc0 frame sync time when it is received at the ground station with **TBD** (10 msec??) accuracy	Used for Vc0 time correlation method. 10 msec accuracy required to maintain S/C to ground time to 100 msec (4.4.3.8.2.1)	GND	2.5 (Ops Concept), 2.6.5 (Standard S/C Services-Comm)					
5.2.5		**Tracking**	Sufficient orbit tracking capabilities shall be provided for the mission	N/A	N/A							
5.2.5.1				Definitive orbit position determination to 120 meters (TBR) accuracy shall be achieved throughout the geosynchronous orbital phase	Required for stationkeeping maneuvers and for HMI orbital Doppler prediction data products	FLT DYN, GND	2.1 (Orbit), 1.5.1 (HMI Dopplergram precision)					
5.2.5.2				Definitive orbit velocity determination to < 1cm/sec accuracy shall be achieved throughout the geosynchronous orbital phase	Required for stationkeeping maneuvers and for HMI orbital Doppler prediction data products	FLT DYN, GND	2.1 (Orbit), 1.5.1 (HMI Dopplergram precision)					
5.2.5.3				Orbit position prediction to 120 m (TBR) accuracy for a period of a week shall be achieved throughout the geosynchronous orbital phase	Required for stationkeeping maneuvers and for HMI orbital Doppler prediction data products	FLT DYN, GND	2.1 (Orbit), 1.5.1 (HMI Dopplergram precision)					
5.2.5.4				Orbit velocity prediction to < 1 cm/sec (TBR) accuracy for a period of a week shall be achieved throughout the geosynchronous orbital phase	Required for stationkeeping maneuvers and for HMI orbital Doppler prediction data products	FLT DYN, GND	2.1 (Orbit), 1.5.1 (HMI Dopplergram precision)					
5.2.5.5				Provide acquisition data to all ground networks supporting post-separation and transfer orbit ops.		FLT DYN, GND	2.5 (Ops Concept)					
5.2.6		**Science Telemetry**										
5.2.6.1			The ground station shall collect Instrument science data in the Ka-Band frequency and directly distribute to the respective SOCs									
5.2.6.2				The ground station shall support the (near) continuous collection of an aggregate science data downlink of 150 Mbps + margin	Based on 130 Mbps science data prior to encoding and margin	GND, INSTR	2.5.4 (Data Delivery)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
5.2.6.3				The ground station shall be capable of autonomously relocking to the downlink in 30 (TBR) seconds after a dropout	Allows rapid reacquisition and accommodation of an onboard Observatory antenna handover	GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.4				The ground station shall employ and demonstrate a data distribution implementation with sufficient margin to support science data retransmissions		GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.5			The ground station shall employ and demonstrate a data distribution implementation with sufficient reliability to achieve error-free data distribution including science data retransmissions			GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.6				The ground station shall directly distribute instrument science data to the respective SOCs with a delivery latency of 3 min (TBR)	Bases on initial Ground system assessment of 1 minute to capture telemetry after transmission from Observatory and 2 minutes to process and send to SOCs	GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.7				The ground station shall provide 30 days of temporary data storage to allow science data retransmission if required	Reflects AO requirement	GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.8				The ground station shall provide science data retransmission from the temporary science data archive with a latency of **TBD** after requested by the SOCs	Implies redundancy in data preservation at ground station or DDC to prevent data loss	GND, INSTR	2.5.4 (Data Delivery)					
5.2.6.9				To ensure retransmission of desired data prior to deletion from ground station data storage, the SOC shall request data retransmission within TBD of initial ground station receipt of science data.		GND, INSTR	2.5.4 (Data Delivery)					
5.3		**Mission Operations Center (MOC)**	**The MOC shall provide all ground data system interfaces required to support Observatory I&T, launch, IOC, and in-orbit operations**	N/A	N/A		2.5 (Ops Concept)					
5.3.1		**Command and Telemetry Functions**	The MOC shall send all commands to the Observatory via the ground stations		Requirement does not preclude SOC commanding, but requires commands to pass through MOC for checking and forwarding to the Observatory	GND	2.5 (Ops Concept)					
5.3.1.1			The MOC shall support the (near) continuous receipt of all Observatory housekeeping data via S-Band telemetry downlink			GND	2.5 (Ops Concept)					
5.3.1.2			The MOC shall provide both real-time and long-term Observatory health and safety ground monitoring functions			GND	2.5 (Ops Concept)					
5.3.1.3			The MOC shall archive and maintain Observatory housekeeping data over the life of the mission			GND	2.5 (Ops Concept)					
5.3.1.4				The MOC shall forward the instrument housekeeping telemetry to the respective SOCs with a maximum nominal latency of 1 min (TBR)		GND	2.5 (Ops Concept)					
5.3.1.5				The MOC shall monitor dedicated ground station operations including housekeeping and science data capture, housekeeping and science data distribution		GND	2.5 (Ops Concept)					
5.3.1.6				The MOC shall provide real-time autonomous health and safety telemetry monitoring and notification	Allows fault detection and unattended operations capability	GND	2.5 (Ops Concept), 2.2.2 (Fault Tol)					
5.3.2		**Data Products**	The MOC shall provide the necessary data products required for the operation and maintenance of the Observatory	N/A	N/A	GND	2.5 (Ops Concept)					

#	CCR# & Date	Title	Functional Requirement	Performance Requirement	Comments	Subsystem Allocation	Trace From	Verify Method	Verf. Lead	Verf. Status	Verf. Data Ref.	Sig Appr
5.3.2.1			The MOC shall provide housekeeping trending capabilities for ongoing monitoring and evaluation of Observatory housekeeping data			GND	2.5 (Ops Concept)					
5.3.2.2			The MOC shall receive science operations plans from the SOCs and generate and uplink science operations plans to the Observatory			GND	2.5 (Ops Concept)					
5.3.2.3			The MOC shall provide flight dynamics capabilities and products supporting attitude determination, orbit prediction and determination, acquisition data generation and delivery, and maneuver planning and execution			GND	2.5 (Ops Concept)					
5.3.2.4			The MOC shall provide ongoing flight software maintenance support to the SDO spacecraft bus			GND	2.5 (Ops Concept)					
5.3.2.5			The MOC shall have the capability to maintain time correlation between the Observatory and the ground segment			GND	2.5 (Ops Concept)					
5.3.2.5.1				Time correlation between the Observatory and the ground system shall be maintained to 100 msec accuracy		GND	2.5 (Ops Concept)					
5.4		**Science Operations Center (SOC)**	**Each SOC shall provide and coordinate all instrument science data collection, archiving, analysis, and science product generation/distribution capability for the Instrument science team**	N/A	N/A	INSTR	Lev.1 [Science Meas. 1-6, 2.1 (Science Obj)]					
5.4.1		**Ops**	The SOC shall provide the capability for science mission planning and command generation		See 5.3.1	INSTR	Lev.1 [Science Meas. 1-6, 2.1 (Science Obj)]					
5.4.2		**Archive**	The SOC shall provide a long term archive of all instrument science and science data products	N/A	Need clarification from science teams on definition of "long term"	INSTR	Lev.1 [Science Meas. 1-6, 2.1 (Science Obj)]					
			Science data products shall be archived consistently with LWS data storage, access, and search requirements			INSTR	Lev.1 [Science Meas. 1-6, 2.1 (Science Obj)]					
5.4.3		**Data Products**	The SOC shall formulate all primary science data products and provide a means for their distribution to the science community	N/A	Comments: "Trace to the SDO Program Data Management Plan (PDMP)."	INSTR	Lev.1 [Science Meas. 1-6, 2.1 (Science Obj)]					