Solar Dynamics Observatory (SDO) Project

System Engineering Management Plan (SEMP)

464-SYS-PLAN-0006

Effective Date: February 02, 2004

Expiration Date: February 02, 2009

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

CM FOREWORD

This document is Solar Dynamic Observatory Project controlled document. Changes to this document require prior approval of the SDO Project CCB Chairperson. Proposed changes shall be submitted to the SDO Project Configuration Management Office (CMO), along with supportive material justifying the proposed change.

Questions or comments concerning this document should be addressed to:

SDO Configuration Management Office
Mail Stop 464
Goddard Space Flight Center
Greenbelt, Maryland 20771

Reviewed By

Barclay, Rich	Mechanisms
Culver, Harry	SDN
Davis, Gary	Propulsion
Defazio, Bob	Flight Dynamics
Gonzales, Pete	Systems Support
Grob, Eric	AIA/Thermal
Hernandez-Pellerano, Amri	SPN
Hughes, Kevin	Verification/Launch Vehicle
Kenney, Tom	GN&C
Keys, Denney	Power
Kim, Paul	Electrical/Harness
Marriott, Richard	Materials
Krus, Dennis	Parts
Lecha, Maria	S-Band
Maldonado, Manuel	Software Systems
Marriott, Richard	Materials
Merrihew, Steve	Instrument Liaison
Miller, Roger	GSE Systems
Morgenstern, Wendy	ACS
Nguyen, Daniel	Thermal
Powers, Mike	Ka-band
Potter, Bill	Grounds System and Mission Ops
Rosanova, Giulio	Mechanical
Schumacher, Steve	C&DH
Scott, Mike	HMI
Straka, Sharon	Contamination
VanBlarcom, John	EVE
Walters, Mark	Flight Software
Xapsos, Mike	Radiation

SDO CCB Members

Schwer, Ken	Project Manager
Lilly, Rob	Deputy Project Manager
Thompson, Barbara	Project Scientist
Robertson, Brent	Observatory Manager
Ruffa, John	Systems Engineering
Ward, Dave	Spacecraft Systems
Calvo, Bob	Systems Assurance Manager
Hewitt, Dennis	Systems Development
Bay, Mike	Systems Support
Anderson, Tom	Instrument Manager
McKenzie, Carlos	Contracting Officer

Solar Dynamics Observatory Project System Engineering Management Plan (SEMP)

DOCUMENT CHANGE RECORD

Sheet: 1 of 1

REV LEVEL	DESCRIPTION OF CHANGE	APPROVED BY	DATE APPROVED
-	Initial release of document by CCR-037	K. Schwer	02/02/04

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

List of TBDs/TBRs

Item No.	Location	Summary	Ind./Org.	Due Date

1.0 INTRODUCTION

1.1 PURPOSE

This plan is intended to document the activities to be performed by the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center's Systems Engineering Team in support of the Solar Dynamics Observatory (SDO) Mission throughout the overall project lifecycle phases. The Systems Engineering Team will review and update this Systems Engineering Management Plan (SEMP) as necessary. At a minimum, the document will be reviewed and re-evaluated at the end of each mission lifecycle phase in order to ensure that the SEMP remains updated, accurate, and relevant to the ongoing systems engineering effort that remains to be completed.

1.2 APPLICABLE DOCUMENTS

The following documents (or latest revisions available) are applicable to the development and execution of this plan:

460-PLAN-0056, SDO Program Plan,
SSE MH2002, Space Science Enterprise Management Handbook
SP-6105, NASA Systems Engineering Handbook
GPG 7120.5, Systems Engineering
GPG 8700.6, Engineering Peer Reviews
NPD 8010.2C, Use of the Metric System of Measurement in NASA Programs
GPG 7120.4, Risk Management
GPG 7120.2, Project Management
GPG 1410.2.1, Configuration Management

1.3 MISSION OVERVIEW

The Solar Dynamics Observatory (SDO) is a cornerstone mission within NASA's Living With a Star (LWS) program. SDO's mission is to understand the nature and source of the solar variability that affects life and society. As such, its principal functions are two-fold. First, it must make accurate measurements of those solar parameters that are necessary to provide a deeper physical understanding of the mechanisms that underlie the Sun's variability on timescales ranging from seconds to centuries. Second, SDO' measurements and analyses must address LWS goals of improving our understanding of how the Earth responds to solar variability, and how that variability and response affect humanity.

The SDO instrument compliment is comprised of three instruments. The Helioseismic and Magnetic Imager (HMI) will be provided by Stanford University in Palo Alto, California. The Atmospheric Imaging Assembly (AIA), will be provided by the Lockheed Martin Solar & Astrophysics Laboratory (LMSAL) in Palo Alto, California. The Extreme Ultraviolet Variability Experiment (EVE) will be supplied by the Laboratory for Atmospheric and Space Physics (LASP) in Boulder Colorado.

The SDO spacecraft bus will be built at GSFC. Integration of the science instruments to the observatory housekeeping systems as well as observatory environmental testing will be performed at GSFC.

SDO is scheduled for launch in April 2008. The observatory will be launched aboard an Evolved Expendable Launch Vehicle (EELV) from the Eastern Range at Kennedy Space Center (KSC). The Launch Vehicle will deliver SDO into a Geosynchronous Transfer Orbit (GTO). Once in GTO, SDO will be required to perform several maneuvers to circularize the orbit and ultimately place SDO into its final inclined geosynchronous orbit slot at 102°West Longitude and an inclination of 28.5 degrees.

Several key elements of the SDO mission drive the operations concept. The chief driver of these is the large volume of data that is to be generated by the spacecraft's solar science instruments. The large data volume can be traced to several instrument characteristics; notably, the combination of state-of-the-art resolution with full disk coverage and increased cadence, which together result in significantly increased data rate over previous missions. The solution to this driving requirement is to place SDO in geosynchronous orbit where it can maintain constant uninterrupted contact with the ground. This allows the high volume of science data to be continuously downlinked to the ground and relayed in near-realtime directly to the principle investigators at their respective Science Operations Centers.

Once on station, SDO will point its instruments toward the sun where they will begin collecting solar science data. Data from the instruments will be passed across the SDO high speed data bus where it will be transmitted to the ground via the SDO Ka-Band RF system. The aggregate science data downlink rate through the Ka-Band system will be 130Mbps (not including overhead). The Ka-band science data will be received by the dedicated SDO ground station located in White Sands, New Mexico. Once through the RF receiver at the station, the science data will be streamed to the Data Distribution System (DDS) co-located with the prime RF station. Science data at the DDS is then sorted, placed in files, and routed accordingly to its destination Science Operations Center (SOC). In addition, a temporary local data archive is maintained at the DDS. This is to allow SOCs to retrieve any data which they may not have received due to a line outage between the DDS and the SOCs.

Instrument operations will be routine for the majority of the mission with instruments running the same science modes continuously. Periodic interruptions to routine science operations are expected. These would include spacecraft momentum dumping, station keeping maneuvers, and instrument calibration maneuvers. Twice a year, eclipse seasons will occur when the view of the science instruments is blocked by the earth on a daily basis for periods of up to ~72 minutes. Two high gain antenna handovers are required each year, causing short data dropouts during the handovers. Data outages are also expected due to precipitation at the ground site because the Ka RF band RF systems are very susceptible to rain attenuation. All of these science operations are captured and quantified in the SDO Project Data Capture Budget (464-SYS-SPEC-0010).

1.4 PROJECT SCHEDULE

Figure 1-1 shows the top-level project schedule for the SDO Project from the pre-formulation phase to the planned mission launch date in April 2008. This schedule has been included in the SEMP for reference only. For the actual latest version of the SDO top-level project schedule, go to the SDO MIS (*https://sdomis.gsfc.nasa.gov*).

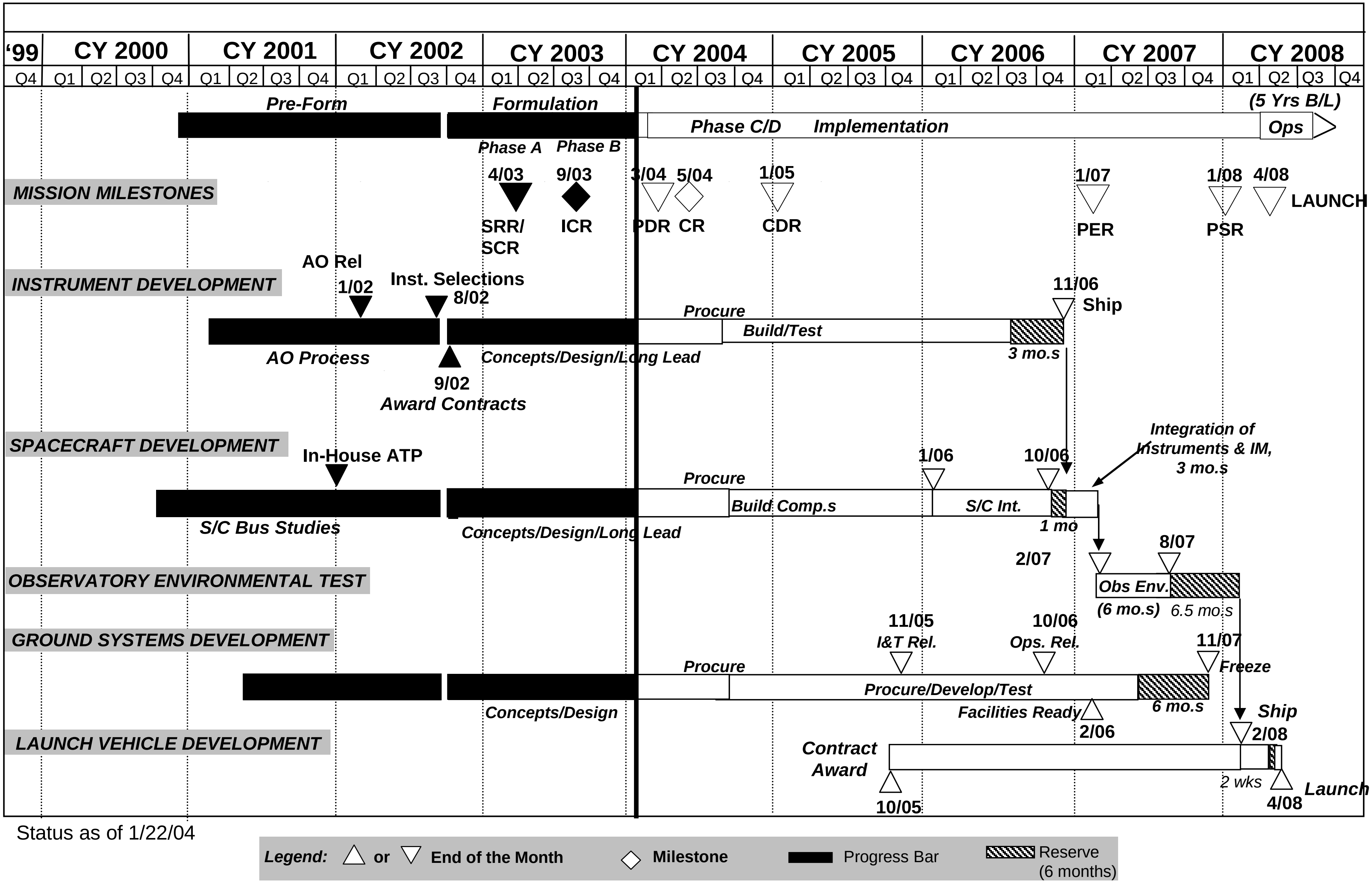


Figure 1-1 SDO Project Top-Level Schedule

2.0 ROLES AND RESPONSIBILITIES

The Systems Engineering Team is organizationally located in the SDO project and also reports to the GSFC engineering directorate as a separate and independent path from the project.

The System Engineering Team is responsible for primary technical coordination of the Mission development & implementation effort over the end-to-end lifecycle of the SDO project, as well as the technical cohesiveness of all of the individual project elements. It is responsible for the following areas:

- Establish the overall framework and procedures for mission requirements identification, management, validation & verification

- Provide technical coordination of the mission system development process. This includes ensuring consistent Requirements, Design, & Ops Concept balanced with cost, schedule & acceptable risk. This process should be designed to follow a logical lifecycle progression (i.e. define multiple approaches, select a single best approach via trade studies, allocate functions to subsystems & components, preliminary design, detailed design, build, verify, operate, dispose)

- As part of Risk Management, ensure that processes are in place that make sure that latent defects are detected & "as built" system will meet Mission Requirements within the bounds of acceptable risk

- Provide control & oversight of technical resources, establishing processes that track and control technical resource allocations throughout the project lifecycle

- Function as Technical Lead & Coordinator for internal and external reviews

2.1 SDO SYSTEM ENGINEERING ROLES

The SDO project organizational chart, shown in Figure 2.1, illustrates the primary project positions and lines of reporting and authority. Figure 2.2 shows the SDO System Engineering Team organization chart. The roles and responsibilities for each of the major elements of the SDO System Engineering Team organization are listed below. Both of these organizational charts have been included in the SEMP for reference only. For the actual latest version of the SDO Project and Systems Engineering Team organizational charts, go to the SDO MIS (*https://sdomis.gsfc.nasa.gov*).

2.1.1 Mission Systems Engineer

The Mission Systems Engineer (MSE) is the leader of the System Engineering Team and is responsible for the overall management and success of the SDO System Engineering effort. He is the principle technical advisor to the project manager. The MSE is responsible for facilitating the resolution of issues between the various members of system engineering team as well as coordinating issues and progress with SDO Project Management. He is responsible for overall leadership and coordination of the SDO systems team, especially in the definition and development of the system requirements, system architecture, and operations concepts, ensuring that these areas remain balanced and in agreement throughout the system lifecycle as part of an overall implementation approach. The MSE is responsible for generating and maintaining the Mission Requirements Document (MRD), which documents the mission Level 2 requirements, and for generating and maintaining the SDO SEMP.

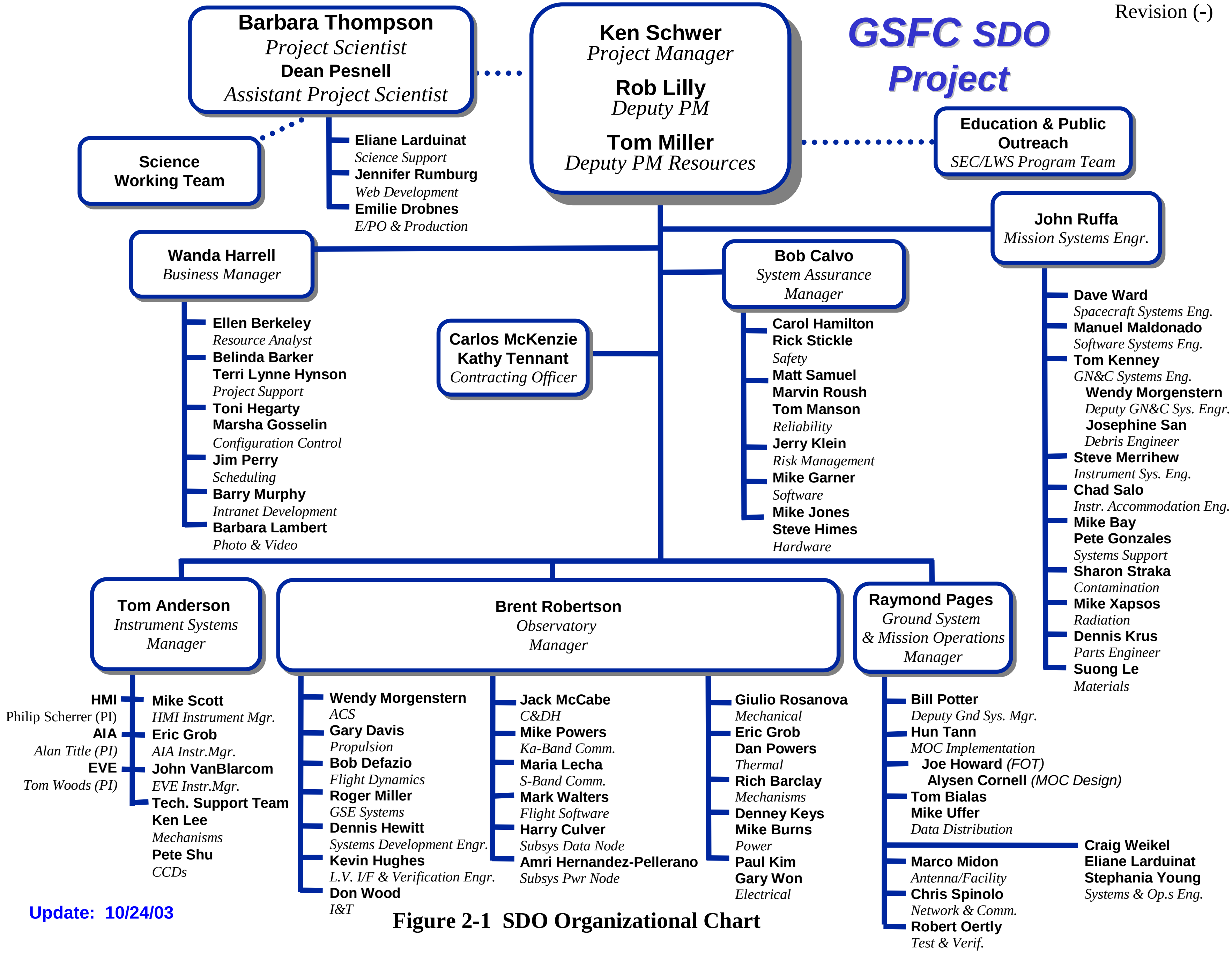


Figure 2-1 SDO Organizational Chart

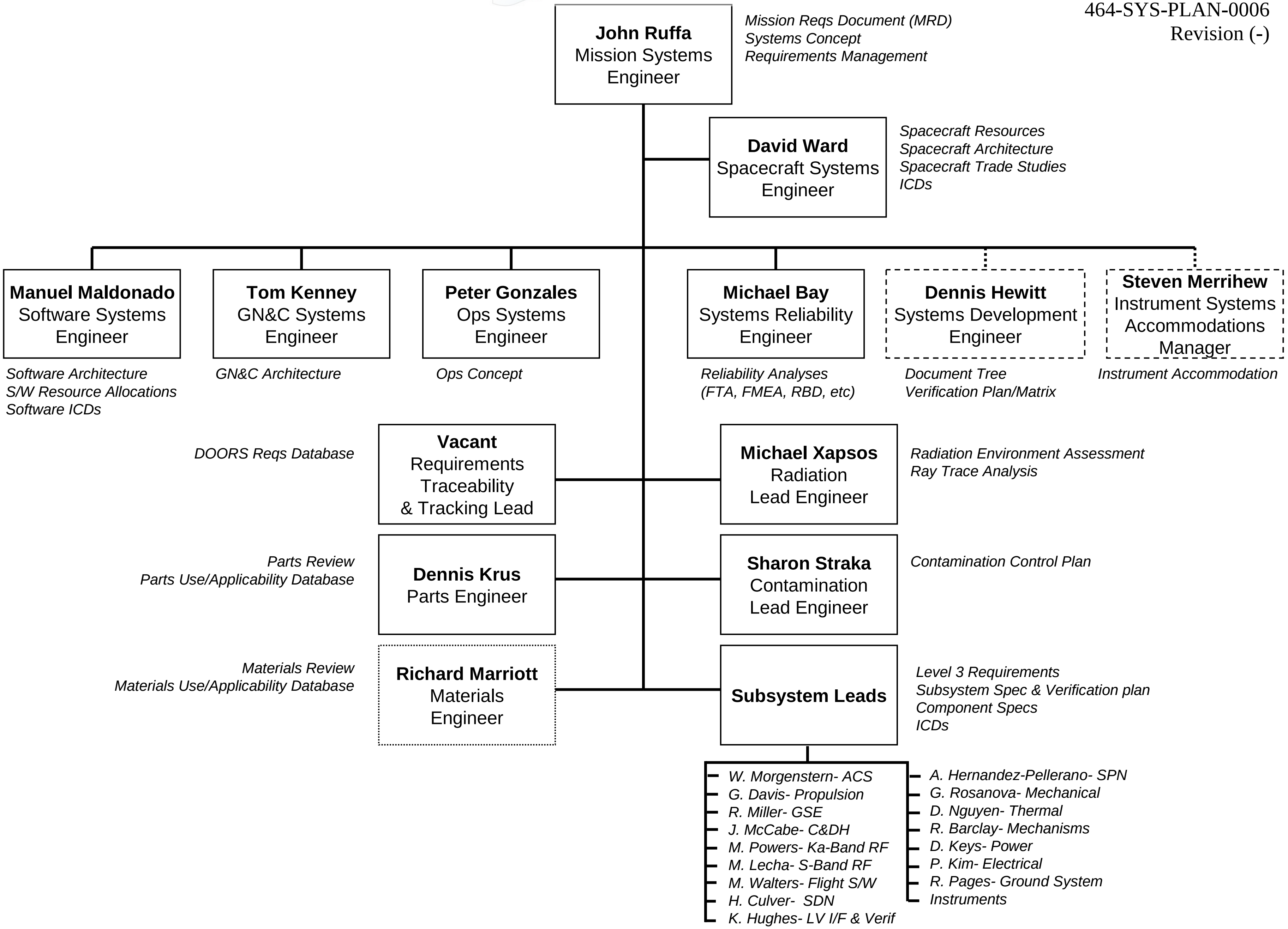


Figure 2-2 SDO System Engineering Team Organizational Chart

2.1.2 Spacecraft Systems Engineer

The Spacecraft Systems Engineer (SSE) is responsible for leading and coordinating the technical development of the SDO Spacecraft, including spacecraft requirements, architecture design, and inputs to the observatory and mission operations concept. He is the primary individual responsible for the development and maintenance of the SDO Spacecraft architecture and provides leadership and oversight of all spacecraft trade studies and performance analyses leading to the spacecraft system architecture design and implementation. The SSE is responsible for the allocation and tracking of all Spacecraft technical resources and is a key leadership member of the SDO Resources Management Board (RMB), an advisory board which evaluates all resource allocation requests and makes key recommendations in the resource Configuration Change Request (CCR) process. He is also responsible for technical oversight on the generation and maintenance of all spacecraft (Interface Control Documents) ICDs.

In addition, the SSE acts as the Deputy to the MSE and is responsible for supporting him in all his tasks and represents him when he is not available.

2.1.3 Software Systems Engineer

The Software Systems Engineer (SWSE) is responsible for technical oversight of all system engineering functions and products all SDO software development activities, including Observatory, Ground System, and Ground Support Equipment (GSE). The SWSE also provides software system coordination and technical oversight in dealing with the SDO instrument teams and all other software component deliveries. In this role, the SWSE is responsible for providing oversight in coordinating the overall SDO software architecture strategy and implementation approach, writing guidelines and procedures defining the software development, implementation, and verification strategy. He provides technical oversight over software resources and allocations and provides advisory inputs to both the SSE and acts a member of the RMB in dealing with all software-related resource activities. The SWSE is responsible for the technical oversight in the generation and maintenance of all Spacecraft software ICDs. Finally, the SWSE is also the SDO project IV&V representative.

2.1.4 GN&C Systems Engineer

The GN&C Systems Engineer (GNCSE) is responsible for oversight over the systems engineering functions and products for the overall GN&C system and provides technical and advisory input to the MSE and SSE over all aspects of the SDO GN&C system. The GNCSE is responsible for requirements generation, trade studies, concept selection, verification and validation, risk management and resource allocation for the GN&C system. The GNCSE is responsible for performing technical trade studies and performance analyses across all GN&C elements and working closely with the SSE to fold these results into the overall Spacecraft and Mission implementation concept. The GNCSE is responsible for the allocation and maintenance of the SDO observatory pointing, jitter and alignment resources. Finally, the GNCSE is also designated as the cross-disciplinary orbit maneuver lead for the SDO mission.

2.1.5 Operations Systems Engineer

The Operations System Engineer (OSE) has primary responsibility for oversight of the operations concept development and verifying that it balances between the mission requirements and the system design architecture. In this capacity, the OSE works very closely with the spacecraft, instrument and ground segment teams to develop an operations concept that coordinates all of these system concepts into a cohesive whole. In addition, the OSE uses this ops concept to assist the Observatory test team in developing and leading the performance verification testing of the SDO Observatory in order to ensure that the "test it the way you fly it, fly it the way you test it" philosophy is adhered to.

2.1.6 Instrument Systems Accommodations Manager

The Instrument Systems Accommodations Manager (ISAM) is responsible for technical oversight and coordination of all Instrument accommodation activities with the SDO Spacecraft, as well as providing technical oversight of Instrument development for the systems team. In this capacity, the ISAM interfaces closely with both Spacecraft and Instrument teams to ensure technical cohesiveness of all accommodation interfaces and resources. Working closely with both the systems team and SDO Instrument Systems Manager (ISM), he provides technical inputs and oversight in the generation and maintenance of all SDO Instrument specifications and Instrument to Spacecraft ICDs.

2.1.7 Systems Reliability Engineer

The Systems Reliability Engineer (SRE) leads the technical analyses evaluating the performance reliability of all SDO flight and ground segments. Through the use of various reliability analysis and assessment tools (i.e. Fault Tree Analyses (FTA), Failure Modes and Effects Analyses (FMEAs), Reliability Block Diagrams (RBDs), Probabilistic Risk Assessments (PRAs), etc), the SRE assesses the reliability of various aspects of the SDO systems and makes recommendations as to how the overall system reliability and performance can be mitigated or improved (within the available resources)

2.1.8 Systems Development Engineer

The Systems Development Engineer (SDE) works closely with the MSE and SSE to define the development, verification and delivery requirements of the SDO Observatory and all it components. The SDE will create and maintain the SDO Document tree, which defines each of the documents required for the SDO throughout the SDO development lifecycle, clearly indicating document responsibility and when it is due. The SDE will assemble and maintain the SDO Verification Plan/Matrix, which identifies the verification requirements for the SDO Observatory and all of it individual components. The SDE will also work with the MSE and SSE to identify and target specific areas of the Observatory development effort that require additional scrutiny and oversight through the development and verification process. The SDE will work with the relevant PDLs in these areas to provide oversight and assistance in the development and verification process.

2.1.9 Contamination Lead Engineer

The Contamination Lead Engineer (CLE) provides contamination assessment and control technical support to the Systems team in evaluating the contamination requirements of the mission through its various lifecycle phases, then in defining and implementing the contamination control plan for the SDO Project. The CLE works closely with the instrument teams and PDLs to assess the contamination risks and impacts, then drafts a Contamination Control plan to be used as an implementation guide through the SDO development lifecycle. This plan is regularly re-assessed and updated to ensure that the appropriate level of contamination mitigation is defined and adhered to.

2.1.10 Radiation Lead Engineer

The Radiation Lead Engineer (RLE) provides radiation analysis, evaluation and assessment technical support to the Systems Team in defining and implementing the radiation requirements for the SDO Project. The RLE performs an initial assessment of the SDO radiation environment, then updates the radiation assessment through the use of additional analysis and tools (i.e. ray trace analyses). In addition, the RLE assists the Parts Engineer in assessing the radiation susceptibility of the SDO flight component parts lists, leading the radiation test regime required for any parts, and working with Product Development Leads and the Parts Engineer to assess any implementation measures that need to be applied to mitigate any radiation concerns.

2.1.11 Requirements Traceability and Tracking Lead

The Requirements Traceability and Tracking (RTT) Lead is responsible for providing the guidelines and procedures for SDO requirements flow-down and tracking. The RTT lead works closely with the MSE to establish the tools and procedures to be used for requirements tracking and traceability, as well as maintaining the requirements tracking system for the SDO Project. The RTT lead supports the systems team in requirements validation, verification, traceability, and tracking through the system engineering lifecycle. The RTT also supports the SDE in developing the SDO verification matrix

2.1.12 Parts Engineer

The Parts Engineer (PE) is responsible for collecting the comprehensive flight parts lists of the SDO Observatory from the PDLs and working with the PDLs to ensure that all flight components meet flight use and implementation requirements. The PE will create and maintain a comprehensive SDO Flight Parts database, which clearly lists, among other things, the following information for each flight part planned for use: its parts qualification level and history, radiation characteristics and use assessment, and parts use and criticality information. The PE, RLE, Instrument teams, and PDLs will use this information to assess the applicability of each part to its planned use in the SDO system design. The PE will, where necessary, alert the PDLs and the System Engineering team to parts application issues and make recommendations on alternate parts if necessary. The PE will regularly meet with the SDO PDLs as well as the MSE and SSE to update them on any use applicability concerns or restrictions that impact the SDO Observatory development effort.

2.1.13 Materials Engineer

The Materials Engineer (ME) is responsible for collecting and maintaining the comprehensive flight materials lists for the SDO Observatory and working with the Spacecraft Development team to ensure that all flight components meet flight use and implementation requirements. The ME will create and maintain a comprehensive SDO Flight Materials database, which clearly lists all of the materials used on the SDO Observatory, where they are used, and any use requirements and restrictions. In addition to meeting and consulting with the PE, Instrument teams, and PDLS, the ME will regularly meet with the MSE and SSE to update them on any use applicability concerns or restrictions that impact the SDO Observatory development effort.

2.1.14 Product Development Leads

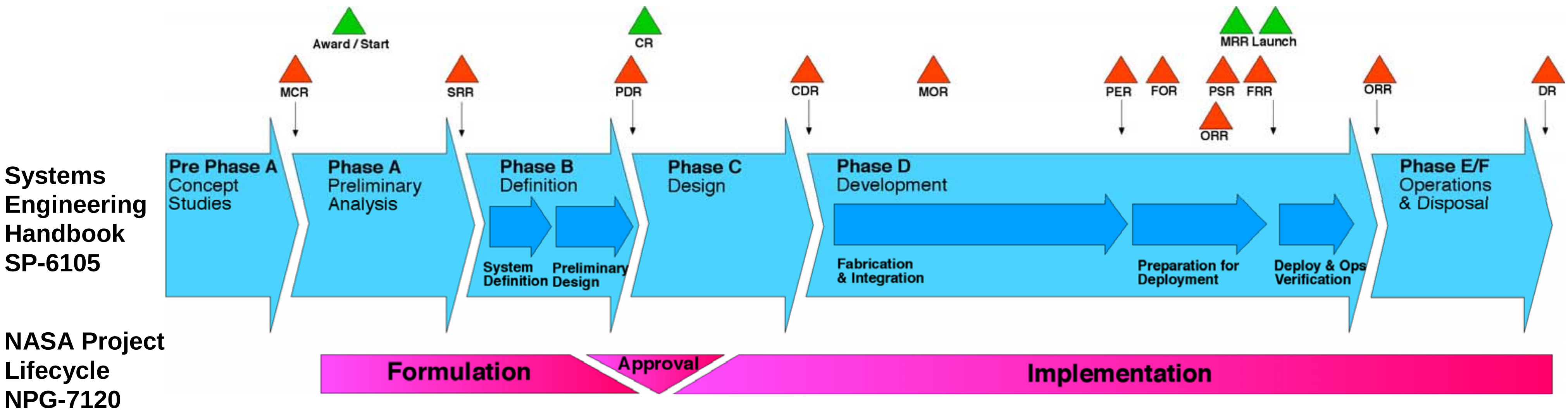
The Product Development Leads (PDLs) are the designated Observatory subsystems leads over the various functional disciplines and development areas of the SDO Observatory (see Figure 2-1). In addition, all of the PDLs are de facto members of the SDO Systems Team and work with the Systems Team in defining, developing, verifying and operating the SDO Observatory. The PDLs will work with the MSE in developing and documenting the MRD Level 2 requirements. In addition, each of the PDLs will derive and document the flowdown of the MRD Level 2 requirements to their own subsystem product Level 3 requirements. These Level 3 requirements, documented in the Subsystem Specifications, will clearly document each derived requirement, its traceability to the Level 2 Observatory requirements as well as when and how it is verified. PDLs are also responsible for the generation and maintenance of any subsystem ICDs, as well as specifications for component procurements. Finally, PDLs are responsible for assisting in the development of the Observatory Level tests that deal with their subsystem performance verification areas.

3.0 SYSTEMS ENGINEERING LIFECYCLE AND ACTIVITIES

The project lifecycle is defined within the Goddard Procedure and Guideline (GPG) 7120.2, Project Management, as a set of phases: Formulation, Approval, and Implementation. The SDO SEMP uses the system engineering phases as described by the NASA Systems Engineering Handbook SP-6105 and the GPG 7120.5, Systems Engineering. These system engineering phases are described as Pre-Phase A, Phase A, Phase B, Phase C/D and Phase E/F. Each system engineering phase consists of functions and a work flow that produces products necessary for completion of the phase and movement into the next. Various mission reviews act as the validating events for each phase and the gates by which the next phase is entered.

Figure 3-1 shows the various phases that together comprise the overall system engineering lifecycle.

- **Conceiving and Developing a Mission is a Sequence of Activities**
  - **"Crawl before you Walk, Walk before you Run"**
  - A) Define Goals, Evaluate Multiple Approaches, Select a Single Best Approach, B) Decompose System to Lower Elements, Validate ("Design the Right System"), C) Detailed Design ("Design the System Right"), D) Build, Integrate, Verify, E) Operate



Pre Phase A
- Define the Mission
- Study Multiple Approaches

Phase A
- Define Top Level Requirements
- Choose a single Approach

Phase B
- Complete the Requirements
- Complete Block Diagrams
- Allocation of Functions & Resources
- Definition of Interfaces
- Preliminary design

Phase C
- Complete the detailed system design,
- Drawings complete
- S/W algorithms complete

Phase D
- Build, integrate, verify, launch the system, and prepare for operations

Phase E/F
- Operate the system and dispose of it properly

Figure 3-1 SDO System Engineering Lifecycle

3.1 SYSTEM ENGINEERING LIFECYCLE OVERVIEW

3.1.1 Phase A

Phase A is the Preliminary Analysis portion of the mission development lifecycle. During this phase, the mission top level requirements are defined, including mission success as well as minimum mission success criteria. As part of the Phase A development process, the development team conducts studies and trades to evaluate a variety of multiple approaches before determining a single "best approach" for the implementation concept, factoring in project execution, cost and schedule constraints.

The products generated during this phase include a preliminary definition of mission requirements, including Level 1 science requirements Level 2 mission requirements. An initial implementation approach is selected that balances the requirements with a proposed architecture design and operations concept, verifying that these three major elements balance together into a viable concept. Preliminary allocations of technical resources are defined in order to ensure that the system architecture is within project constraints. This phase includes a Mission Definition Review (MDR), which provides preliminary identification and review of the mission definition parameters. The MDR includes verification & agreement of top-level SDO mission requirements and a presentation of a baseline implementation concept as well as an initial assessment of the soundness of this concept before proceeding on to further definition

Phase A is completed by a System Requirements Review (SRR) and System Concept Review (SCR) to ensure that the requirements are clearly understood and that the proposed concept meets the documented requirements.

3.1.2 Phase B

Phase B is the system definition portion of the mission development lifecycle. During this phase, the development team focuses their effort to make sure that they "design the right system"; that is a system that meets the intent of the mission objectives as defined by the mission requirements (subject to the identified programmatic resources and constraints).

To this end, the development team works to complete the requirements definition down to the subsystem level or Level 3 requirements. The flowdown and traceability of requirements both from Level 1 down to level 3 and across subsystem lines are evaluated and validated. Once this is completed, the implementation concept is further refined and the balance between requirements, architecture design, and ops concept is further evaluated and balanced. During this phase, the development of early breadboards may be used for risk reduction.

Phase B culminates in a series of subsystem Preliminary Design Reviews (PDRs), which assess the compliance of each subsystem preliminary design against the applicable requirements and evaluates the readiness of each to proceed with detailed design. The Phase B review process culminates in a Mission-level PDR, which assess the overall compliance of the Mission preliminary design relative to the mission requirements and evaluates the readiness of the project to proceed into the detailed design phase.

3.1.3 Phase C

Phase C is the detailed design and development portion of the mission lifecycle. During this phase, the development team further refines the preliminary design into a completed implementation design that can be fabricated, integrated, and verified. During this phase, detailed design breadboards may be used for initial design functionality verification. Later, additional higher fidelity engineering test units more closely resembling the anticipated flight article are built and tested in order to increase confidence in the flight design and performance.

During this phase, technical parameters, schedules, and budgets are closely tracked to ensure that undesirable trends against technical resources, performance margins, or development resources are recognized early enough to take corrective action.

The end of Phase C is marked by a series of subsystem Critical Design Reviews (CDRs), which are held prior to the start of fabrication/production of the actual flight product or end item. The CDR evaluates the completed detailed design of the subsystem flight products in sufficient detail that approval for actual flight production can proceed. The Phase C review process culminates in a Mission-level CDR, which assess the overall compliance of the Mission detailed flight design relative to the mission requirements and evaluates the overall readiness of the project to proceed into flight item or flight system production.

3.1.4 Phase D

Phase D is the development portion of the mission lifecycle. During this phase, the development team actually produces and verifies the performance of the system designed in the previous phase. This development starts at the component level, where component level production, integration, testing and verification takes place. As the individual mission components are verified and delivered, the mission-level integration, testing and verification takes place for the eventual completion and verification of the overall flight system and support elements.

This phase also include pre-launch training, pre-launch campaign and launch site activities, Observatory launch, orbit insertion and in-orbit checkout (IOC). The end goal is the presentation of a final system operating in its intended operational environment capable of accomplishing the mission objectives for which it was designed.

During this phase, Test Readiness Reviews (TRRs) act as major control gates at all levels of component integration (from component level to full system level), ensuring that clear test plans/procedures are in place to adequately test the item in question prior to proceeding, as well as verifying that the item in question is ready for testing. System Acceptance Reviews (SARs) or Pre-Ship reviews (PSRs) are used to assure that the item has been validated and verified through the environmental qualification and/or acceptance test program, that test results were adequately reviewed, that all open items have been satisfactorily addressed and closed. As part of the overall system, the Flight Readiness Review (FRR) will be used to assure final technical readiness for launch by demonstrating that all requirements have been verified, all open items including problem reports have been closed or appropriately dispositioned.

Also in this phase, from a test and operations point of view, test and operations procedures are developed and verified, as well as the ground systems and databases used to implement them. The systems testing used closely mimics the anticipated flight configurations and operations in order to follow the "test it like you fly it" philosophy. Contingency flowcharts and procedures are developed and tested to allow quick recovery in the event of system anomalies.

This phase culminates in the launch of the Observatory, the successful insertion into the desired orbit, and the completion of the planned in-orbit checkout (IOC) activities. At the end of this phase, the complete system is operationally ready to perform its intended mission functions and objectives.

3.1.5 Phase E/F

Phase E/F is the operation and disposal portion of the mission lifecycle. During this phase, the system is actually operated in the manner in which it was designed in order to meet the initially identified mission objectives. The products of this phase are the results of the mission. This phase also includes appropriate decommissioning and disposal of the system when it has completed its mission

3.2 KEY SYSTEMS ENGINEERING FUNCTIONS

The major goal of system engineering is coordinating the engineering, design, and development of a System Architecture and Design that meets the Requirements and is consistent with the Operations Concept, all within the appropriate project resource constraints. The primary responsibility of the System Engineering team is to initially balance these elements into an initial system implementation and keep these three elements carefully balanced throughout the project engineering lifecycle. Figure 3-2 illustrates these three major system design implementation elements and the need to keep them balanced through the project development and implementation lifecycle.

The Three Major Functions Must Lead to a Balanced Design that is Consistent with Project Cost, Schedule and Risk

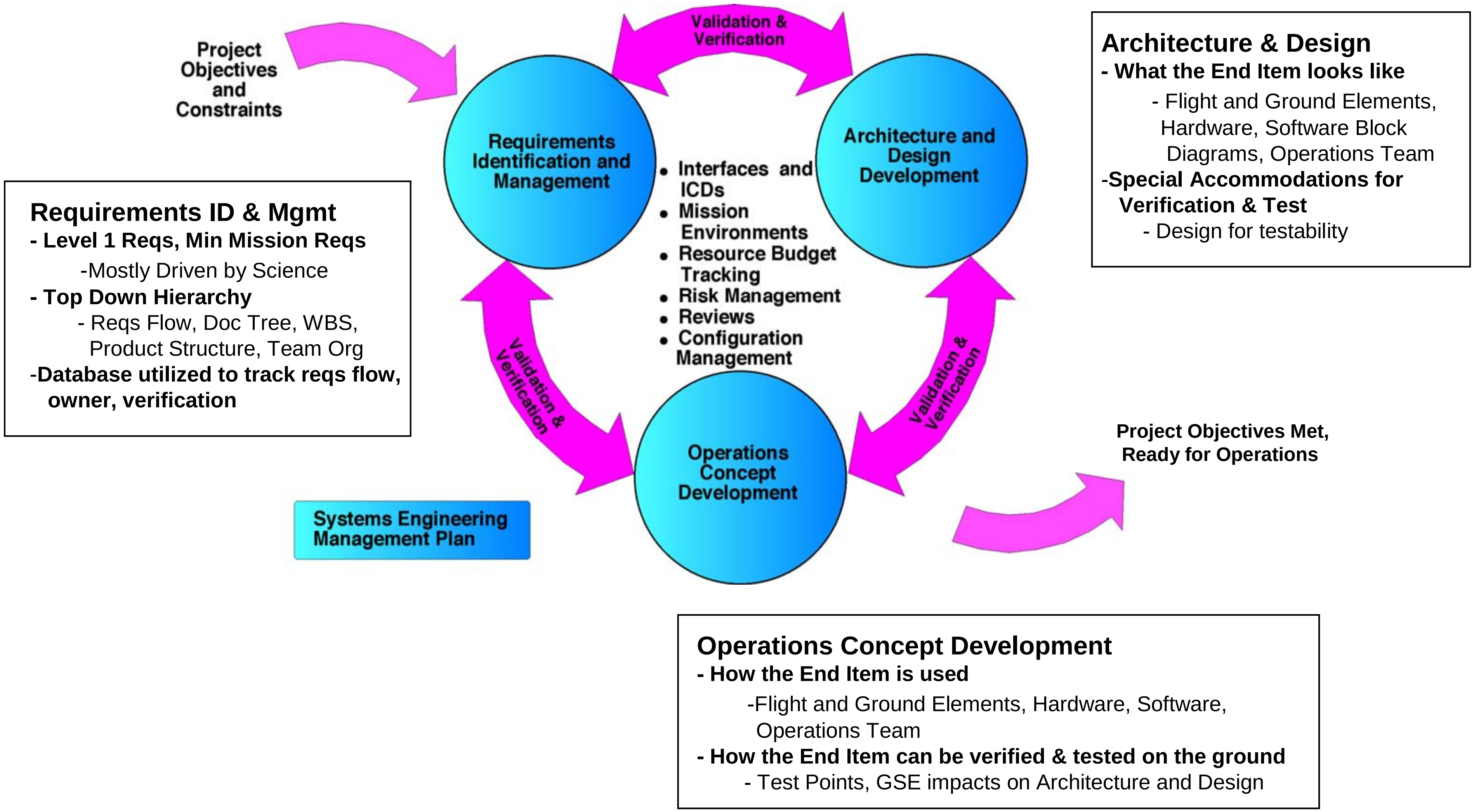


Figure 3-2 Balancing the Major System Implementation Elements

The following key system engineering functions provide the key elements to assist the Systems Engineering team in developing a balanced system implementation and maintaining the balance throughout the project lifecycle.

3.2.1 Understanding the Objectives

Clearly describing and documenting the mission objectives is important to making sure that the project team is working towards a common goal. Translating the Science Objectives into specific Science Measurements, then into Level 1 Science Requirements defines the fundamental basis for performing the mission.

The mission objectives should include a description of a measurement concept, an instrument concept, and program constraints. The measurement concept describes the characteristics of the measurements to be made. The instrument concept describes what instrument characteristics are needed to make the measurements and often provide additional design implementation details. Program constraints are also identified and serve to bound the implementation design to the appropriate resource levels.

The definition of mission objectives culminates with a set of full and minimum Level 1 mission requirements. The Level 1 requirements represent an agreement between the project and headquarters and should be clearly defined and approved by headquarters and center management by the end of Phase B. Any modifications to the Level 1 requirements must be approved by headquarters and GSFC center management.

3.2.2 Operations Concept Development

The operations concept describes how the implemented mission is tested, verified, launched, deployed, commissioned, operated and disposed of. The operations concept is an integral part of the initial system implementation concept, along with the mission requirements and architecture design, and is used to verify the validity of the concept as part of the initial design process. Later in the design lifecycle, the ops concept evolves into the mission or flight operation plan. The SDO mission operations concept is documented in the SDO project Operations Concept Document (464-GS-PLAN-0010).

A brief summary overview of the SDO operations concept consists of the following mission phases, shown in Table 3-1.

<table>
<tr><th>Mission Phase</th><th colspan="2">Description</th></tr>
<tr><td>Prelaunch Operations</td><td colspan="2">Includes ground testing and verification of the assembled Observatory, as well as end-to-end system verification and prelaunch planning</td></tr>
<tr><td>Launch & Acquisition</td><td colspan="2">Phase covering pre-launch configuration until Observatory is power-positive and pointing at the sun
- Launch, separation, XPNDR power on, S/A deployment & RW power, sun acquisition</td></tr>
<tr><td>In-Orbit Checkout & Orbit Circularization</td><td colspan="2">Phase used during first weeks to checkout and calibrate Observatory
-S/C modes verified, Ka-band deployed & verified, initial instrument checkout
- Orbit Circularization Occurs during In-Orbit Checkout (IOC), with several burns needed at Apogee to raise orbit to GEO</td></tr>
<tr><td>Instrument Commissioning</td><td colspan="2">Begins once SDO is on-station and Ka-Band downlink has been established. Phase lasts 60-90 days
-Includes instrument optical system checkout, calibration maneuvers and commissioning activities</td></tr>
<tr><td rowspan="7">Science Mission Phase</td><td colspan="2">Expected to be phase that mission stays in 99% of time once at GEO. Dominated by routine continuous instrument operations with few other operational activities planned</td></tr>
<tr><td colspan="2">Science Mission Phase Activities/Modes</td></tr>
<tr><td>Normal Mode</td><td>Continuous routine uninterrupted instrument operations
- Science data transferred first to ground, then to SOCs, all on a continual basis (24/7)</td></tr>
<tr><td>Periodic Calibrations/ Housekeeping</td><td>Interruptions in normal science phase needed for maintaining science quality
- Instrument calibration maneuvers, Instrument alignment calibrations, HGA pointing calibration</td></tr>
<tr><td>Eclipse Seasons</td><td>Principal Observatory requirement in this phase is to survive and minimize impact on science operations
- Power storage and thermal (instrument optical bench and spacecraft) considerations</td></tr>
<tr><td>Stationkeeping & Momentum Management</td><td>Required operations to keep SDO within its orbit “slot” and maintain Observatory angular momentum near zero
- Planned to interrupt science once per month</td></tr>
<tr><td>Safehold & Emergency Modes</td><td>Several capabilities will exist on the Observatory for “safing” in the event of an anomaly
- Fault detection/correction, autonomous safehold, 1553 safing notification, power subsystem load shedding</td></tr>
<tr><td>Disposal</td><td colspan="2">At end of mission, NASA requires disposal of SDO into an orbit that won’t interfere with other spacecraft
- Increase altitude to >300 km above GEO orbit, Passivate energy sources</td></tr>
</table>

Table 3-1 SDO Mission Phases

3.2.3 Architecture and Design Development

The major goal of system engineering is coordinating the engineering, design, and development of a system architecture and design that meets the Requirements, is consistent with the Operations Concept, and follows a valid Operations Concept, all within the appropriate project resource constraints.

3.2.4 Requirements Identification and Management

The requirements define the functions and performance levels of a system and form the fundamental basis for defining the system. The definition, traceability, tracking and maintenance of system requirements is one of the fundamental responsibilities of the System Engineering team.

The requirements should be organized into a hierarchy that flows down through the system in question, tracing the requirements from the most top-level to the most detailed and specific, usually from the mission to the primary mission segments down to the subsystem and components level. A document tree is typically used to show both the level of requirements as well to define the documentation in which the requirements will be captured. Appendix B contains the SDO Document Tree in which the SDO documents hierarchy is captured and system requirements are defined.

The DOORS (Dynamic Object Oriented Requirements System) requirements management database will be used by the systems team as an ancillary tool to assist in SDO requirements management. SDO requirements will be entered into the DOORS database to further evaluate and refine requirements flowdown and traceability as part of the requirements development process. In addition, the DOORS database will be used to trace impacts of requirements modifications throughout the development process.

3.2.5 Validation and Verification

Validation and verification work together over the systems engineering lifecycle to show that the system implementation meets its desired objectives.

Validation is used to ensure that the mission implementation design will meet the mission objectives, using a continuing process of re-evaluating the mutual consistency of Requirements, Architecture and Design, and Operations Concept against each other. In other words, the goal of validation is to ensure that the team builds the “right system”, one that meets the intent of the mission objectives.

Verification includes those functions that make sure the team builds the “system right”, by verifying the design and implementation against the stated requirements. The first step of system verification is to ensure the verification process for each requirement is clearly delineated

3.2.6 Interfaces and ICDs

ICDs provide the details on how various system elements need to interact with each other as part of the overall system integration or operation. By clearly defining and documenting interfaces, the development and detailed design of the various system elements can proceed in parallel.

Specifications and ICDs will be used by the SDO Systems Engineering team and all subsystem PDLs in order to define subsystem and component performance requirements and operational parameters, as well as to communicate pertinent interface definition requirements across subsystem and engineering discipline lines.

All specs and ICDs shall adhere to the SDO Configuration Management Procedure (document # 464-PG-1410.2.1) and must employ appropriate review and signoff procedures prior to initial signoff and as a part of any future modifications or changes.

3.2.6.1 SDO Units Policy

The NASA Units Policy is contained in NASA NPD 8010.2 "Use of the Metric System of Measurement in NASA Programs". A brief summary of this policy can be condensed to the following

- Flight projects should adopt metric measurements as preferred system of weights and measures
- Controlled use of hybrid units is permitted where full implementation of metric system is not feasible

The SDO units implementation policy follows the following guidelines:

a. Flight & Ground Operational Software shall use exclusively Metric units (includes Flight operational products & deliverables, such as algorithms and analysis)

   - Rationale: Limits opportunity for error in system with highly complex verification process; difficult to find flight units errors prior to flight; various combinations of components & parameters may not be completely exercised or tested

b. ICDs may use metric units with English equivalent where necessary (typical for some mechanical items and Launch Vehicle)

   - Areas that are more easily verified via ground inspection, assembly, testing prior to flight

c. Manufacturing drawings can be English to enable use of US manufacturing facilities

d. Identify where Metric units are not used per NASA NPD 8010.2C.

The plan for the prevention of misapplication of units is implemented/tracked by the Systems Engineering team and is summarized below:

a. Identify categories where units error could result in loss of mission (ICDs, drawings, analysis, models, etc)

   - Identify in each subsystem where units error could cause mission loss; initial list required by PDR

b. Decide and document areas where ground verification and testing may not catch units error

  - Reviews, inspections, tests; Identify areas where ground testing might not catch errors where English units are misapplied

c. Track the defenses against misapplication of units; Correct identified potential mission critical units errors

  - Utilize spreadsheet or database to record and track items

3.2.7 Mission Environments

Mission environments deal with the unique set of environmental requirements that apply to all flight segment elements. These encompass the conditions that can be expected to be encountered during ground test, storage, transportation, launch, deployment and normal operations from beginning to end-of-life. Like all other requirements, the environmental requirements must be clearly documented and disseminated to the system elements so that they can be incorporated as part of the overall implementation concept. SDO Mission environments are captured in document # TBD.

3.2.8 Technical Resource and Budget Tracking

The Systems Engineering team is responsible to identify the mission resources to be allocated and tracked at the project level, as well as to define acceptable resource margins and set up a margin management philosophy based on the various stages of the mission lifecycle phases.

Table 3-2 shows the SDO System Engineering resource allocation margin approach as the project development lifecycle proceeds through the various phases of mission development. The resource margins required decrease as the system development progresses to further levels of definition and maturity

Total Margin Progression	SCR	PDR	CDR	Flight
Mass	30%	25%	15%	0
Power (solar array, battery, load)	30%	25%	15%	0 at EOL
Propellant	Margin detailed w/ Prop Budget			3 Sigma
Memory	50%	40%	30%	25%
CPU	50%	30%	25%	20%
Telemetry and Commands	20%	15%	10%	5%
1553 Bus Bandwidth	20%	15%	10%	5%
RF Link	3dB	3dB	3dB	3dB

Table 3-2 SDO Resource Margin Progression

In addition, as the maturity of the system architecture increases, the precision of the resource estimates will improve with the method of estimating the resources required. Table 3-3 illustrates the SDO margin factors that will be applied to the system elements as they progress through the various levels of development maturity.

SDO mass and power estimates and allocations are recorded and maintained in separate documents, with Mass and power allocations under CM control. SDO mass allocations are documented in 464-SYS-SPEC-0007 and estimates in 464-SYS-SPEC-0020. SDO power allocations are documented in 464-SYS-SPEC-0008 and estimates in 464-SYS-SPEC-0021.

Margin Factors	Estimate	Calculated	Measured
Mass	20%	15%	5%
Power (solar array, battery, load)	20%	15%	5%
Propellant	Margin detailed w/ Prop Budget		
Memory	30%	15%	5%
CPU	50%	30%	25%
Telemetry & Cmds, 1553 bus	20%	15%	10%
RF Link	2dB	1dB	.5dB

Table 3-3 SDO Resource Margin Fidelity Factors

3.2.9 Risk Management

Risk management is an organized, systematic decision-making process that identifies, analyzes, plans (for the handling of risks), tracks, controls, communicates, and documents risks to increase the likelihood of achieving project goals. The Systems Engineering team plays a pivotal role in leading the risk management process by identifying, analyzing, planning, tracking, controlling, communicating and documenting risks and reporting them to SDO Project Management.

In order to identify, assess, and track SDO development risk items, the SDO Systems Engineering Team will utilize the SDO Risk Management process detailed in the SDO Risk Management Plan (Document # 464-SA-PLAN-0003).

3.2.10 Lifecycle Milestone Reviews

Reviews are held to validate the quality and completeness of a system engineering phase or portion of work and are a communication tool both to an external audience as well as to within the development team itself.

Reviews are critical and important for the development of hardware and software. They allow the team to collect the relevant and important information, make sure the information is consistent and then benefit from comments and suggestion from peers outside the organization.

Action items from the reviews will be included in the project action item database and will be closed with concurrence of the initiator and the review lead. The Mission Systems Engineer is responsible for the action item database.

3.2.10.1 Review Definitions

The following generic objectives will be used for the mission, subsystem, and component reviews (as applicable), tailored to the applicable "system of interest". Reviews which have already occurred are denoted with the actual date of the review.

Mission Definition Review (MDR)- 12/02
Objective: Verify the understanding & agreement of top-level SDO mission requirements; identify secondary implementation requirements and demonstrate their traceability to top-level requirements. Present updated baseline implementation concept and perform an initial assessment of the soundness of this concept before proceeding on to further definition. This assessment should include the following criteria: Does the implementation concept address and meet the Mission Requirements? Is the flowdown of requirements clearly identified and their impact on system design understood? Does the implementation concept address the driving requirements/issues and are major trade studies identified? Does an initial assessment indicate that the implementation fits into the technical resource constraints of the project? Is a process being put into place to identify and manage project technical resource budgets and constraints?

Systems Requirements Retreat (SRR)- 2/03
Objective: Evaluates the completeness, consistency, and achievability of Science and Mission (Level 1 and Level 2) requirements necessary to fulfill the mission objectives, as well as evaluating the traceability of the requirements flowdown. This review asks the following questions: Are we sure we have all the right requirement? Are all the critical requirements captured in the Mission Requirements Document (MRD)? Are the stated requirements correct? If not, how do we make them correct? Are the requirements properly allocated to specific subsystems? Do subsystems understand and agree to the requirements they are allocated?

Systems Requirements Review/Systems Concept Review (SRR/SCR)- 4/03
Objective: Demonstrate that the system requirements are clearly defined and reflect mission objectives. Demonstrate that the Mission architecture/design/operations concept fulfills mission objectives and can be built within the project constraints. Show that functional requirements and system implementation is derived from top-level mission requirements, with clear requirements flow down and allocation to specific mission subsystems. Demonstrate that a preliminary development flow and preliminary product verification program are defined. Demonstrate mission requirements, architecture/design, and operations concept is developed and documented at a level sufficient to proceed into preliminary design

The SDO SRR/SCR goals, objectives, and criteria are detailed in Appendix C.

Preliminary Design Review (PDR):
Objective: Ensure that all system requirements have been allocated, the requirements are complete, and the flow-down is adequate to verify performance. Demonstrate that the

preliminary design meets all system requirements, system level interfaces are defined, and the system can be implemented within project constraints. Show sufficient maturity in the proposed design to proceed to final design. Show that the design is verifiable and that the risks have been identified, characterized and mitigated as appropriate. Reviews of elements that make up the system will be summarized.

The SDO PDR goals, objectives, and criteria are detailed in Appendix D.

Critical Design Review (CDR):
Objective: Disclose the complete design in detail and ensure that the design maturity and process controls justify the decision to initiate fabrication/manufacturing, integration and verification of mission hardware and software. Reviews of elements that make up the system will be summarized.. Demonstrate mission requirements, architecture/design, and operations concept is developed and documented at a level sufficient to proceed into flight item or flight system production.

Pre-Environmental Readiness (PER)/ Test Readiness Review (TRR):
Objective: Evaluate the planned test/calibration program and test flow to assure that it meets the system's or subsystem's verification needs. Assure that a proper baseline of performance of the item to be tested has been established, that the item is ready to begin a qualification test program to demonstrate performance, and that open items that could effect changes to the system have been appropriately dispositioned. Verify that appropriate protection devices are planned and that the test setup will be verified. Verify that the procedures and test personnel are ready. Reviews of elements that make up the system will be summarized

Pre-Ship Review (PSR)/System Acceptance Review (SAR):
Objective: Assure that the item or system has been validated and verified through the environmental qualification and/or acceptance test program, that test results were adequately reviewed, that all open items have been satisfactorily disposition, and that the item is ready for shipment. Assure that the required documentation and plans for the next level of integration are adequate and complete. Reviews of elements that make up the system will be summarized

Flight Readiness Review (FRR) (Technical)
- 3 days prior to management FRR
Objective: Assure final technical readiness for launch by demonstrating that all requirements have been verified, all open items including problem reports have been closed or entered into a mission residual risk list with appropriate rationale for acceptance. Each subsystem and instrument lead justifies why they are declaring their flight hardware / software, support equipment, and operational procedures ready for flight. Results of this review flow into the Project Manager's readiness assessment at the Flight Readiness Review.

Operations Readiness Review (ORR)
Objective: Assure that the system is ready to transition into an operational mode through examination of system characteristics and procedures used in system operation (normal and contingency), that documentation is complete and represents the system in all planned modes of operation, and that adequate training is in place with demonstrated capability to support all aspects of system maintenance, preparation, operation, and termination. Plans and resources necessary to transition from flight test to operational status through mission life are in place

Decommissioning Review
Objective: Assure that the reasons for decommissioning are valid and appropriate, as well as examining the current system status and plans for disposal. Demonstrate that the plans and resources for decommissioning and disposal are adequate and in place and meet NASA guidelines. Ensure that archival plan shave been completed for essential mission and project data.

3.2.10.2 Subsystem Reviews

The Subsystem PDLs are responsible for the following reviews. For each of the reviews, the Subsystem PDL will generate the agenda and plan the review. The PDL will work with the SDO project to select the Review Chairperson and assist the Review Chairperson in collecting action items. The PDL ensure that the MSE receives a summary of the review and any lower level component reviews, including any action items for the Mission Systems Engineer (see Section 3.2.10.2.1 for more information on the review process and review products)

The following Subsystem Level Peer Reviews are planned. These reviews will be planned by the subsystem lead and will be used to lead up to mission level reviews. Subsystems that are integrated at a subsystem level will have TRR and Acceptance Reviews.

Review Element	PDR	CDR	TRR	Accpt
C&DH	Y	Y	Y	Y
Comm (S & Ka- Band)	Y	Y	Y	Y
Electrical Systems	Y	Y		
FDS	Y	Y		
Flight Software	Y	Y		
ACS	Y	Y		
Ground System	Y	Y		
Antenna (Grnd Sys)	Y	Y	Y	Y
DDS (Grnd Sys)	Y	Y	Y	Y
MOC/FDS (Grnd Sys)	Y	Y	Y	Y
Networks & Comm. (Grnd Sys)	Y	Y	Y	Y
Operations (Grnd Sys)	Y	Y	Y	Y
GSE	Y	Y		
HGAS	Y	Y	Y	Y
Power	Y	Y		
Propulsion	Y	Y	Y	
Mechanical	Y	Y		
Systems Engineering	Y	Y		
Thermal	Y	Y		

Table 3-4 Planned Subsystem-Level Peer Reviews

3.2.10.2.1 Subsystem Review Teams and Peer Review Process

All subsystem and component peer reviews shall be led by a Review Chairperson who is appointed as a part of a joint selection process between the SDO Project and the Subsystem PDLs. The SDO Observatory Manager will coordinate the review chairperson selection with each of the SDO Subsystem PDLs, while SDO Ground System Manager and the SDO Instrument Systems Manager will coordinate this selection process with the respective ground system and instrument teams. The SDO Observatory Manager, Ground System Manager, and Instrument Systems Manager will report on the identification and nomination of candidates to the SDO Project Manager, who provides final approval to the peer review chairperson selection process. Once selected, the Review Chairperson shall recruit the other review team members and present their names to the SDO project and Subsystem PDL. The subsystem peer review teams shall be comprised of technical experts with significant practical experience relevant to the technology and requirements of the system, component, etc. to be reviewed. Both the Review Chairperson and the review team members should be sufficiently independent from the project and product teams to ensure a thorough, independent review with a variety of perspectives, experiences, and processes considered. The Review Chairperson and review team members should be selected with the consideration that they will continue on throughout the subsystem product lifecycle review process for which they were initially selected, maximizing the value to the project and subsystem team.

In addition to selecting the review team members, the Review Chairperson is responsible for coordinating the actual review with the Subsystem PDL. The Review Chairperson presides at the review, moderating question and answer periods and collecting RFAs from review team members and other participants. If any splinter sessions appear warranted, the chairperson shall coordinate these with the Subsystem PDL and make sure that the review team is adequately represented. At the conclusion of the review, the review Chairperson shall summarize the review team's impressions and review the RFAs (Request for Action) for clarification of language and for information to the project/subsystem product team. The chairperson shall submit the complete set of RFAs as well as a brief report including summary impression and findings to the Subsystem PDL within 30 days of the completion of the review.

The Subsystem PDL is responsible for the collection and archiving of all review materials. This includes the review materials, any supporting analysis or documentation, attendance list, and all RFAs generated from the review process. The RFAs shall be entered into the SDO Action item Database for tracking by the SDO project to ensure their disposition and closure. It is recommended that the Subsystem PDL collect and assemble the review materials and documentation into an electronic PDF file for archival purposes and forward to the SDO CM office for their records.

In preparation for the review, the PDL is required to query the GSFC on-line Lessons-Learned Information System (LLIS) (*http://llis.gsfc.nasa.gov/*) to determine if there are applicable lessons relating to the development of the SDO mission and its components (see Section 4.3.1). The development team will include on any applicable results as in the review presentation part of the development peer review process.

The Subsystem PDL is responsible for the implementation/resolution of all RFAs and the preparation of responses to the review team. Once RFA responses are generated, the Subsystem PDL shall submit them to the Review Chair for closure. RFAs shall be submitted either as a combined group of all RFAs or a subset as RFAs are addressed and closed- the precise approach will be determined through discussions between the Subsystem PDL and the Review Chair. The Review Chairperson and RFA originator shall review the RFA responses for acceptability and inform the Subsystem PDL and SDO Project Manager of their decisions in writing. The Subsystem PDL is responsible for reporting and updating RFA status (Open, Closed, Contested) within the SDO action item Database and to the SDO Project Manager. The Subsystem PDL, Project Manager, and Review Chairperson shall work together to attempt to resolve any differences of opinion on RFA status or responses. Any unresolved differences will be identified as candidates for entry into the SDO Risk Management System for assessment and resolution. Any contested RFAs shall be designated such in the RFA response and Action Item Database until they are resolved.

The SDO development team will, at each higher level review, summarize the outcome of all lower level reviews at an appropriate level of detail. This hierarchical process allows design issues, review findings, design mitigations and changes, and critical RFA outcomes to flow upward through the various levels of the review process, summarizing both the work and the review process leading up to each major mission review.

3.2.10.3 Component Reviews

A Component Lead Engineer (CLE) is the assigned lead for a specific SDO component or item. In some cases, where a subsystem consists of a single component deliverable, the CLE is also the PDL. In most cases, the CLE works as part of a team under the oversight of the PDL, who is responsible for the coordination of the complete subsystem.

The Component Lead Engineer is responsible for the following reviews. He will generate the agenda and plan the review. He will select any outside reviewers and collect action items. He will summarize the review including any action items for the applicable Subsystem PDL.

Component Level Peer Reviews are planned for the following Subsystems (see Table 3-5). These reviews will be planned by the subsystem lead and will be used to lead up to the subsystem and then mission level reviews. Component level reviews will be indicated on the Subsystem Level Schedules. This table will be updated as component suppliers are identified. Possible subsystem components requiring reviews are listed in italics next to the applicable subsystems in Table 3-5

Only major components (as determined by SDO Project) will require full component reviews. In addition, in cases where an existing component design is being used, the SDO Project may assess and choose whether a Design Compliance Review may be implemented in lieu of a full-blown Design Review with an independent review chair and a full review team. The purpose of this compliance review would be to verify that the existing design has sufficient heritage and previous review and/or flight history to alleviate the need for a more detailed review and that the existing design fully meets the SDO requirements.

Review Element	PDR	CDR	TRR	Accpt
C&DH *(C&DH Box)*	Y	Y	Y	Y
Comm *(XPNDR, Ka-Amplifier, Ka-Antenna)*	Y	Y	Y	Y
Flight Software	Y	Y	Y	Y
ACS *(IRU, ST, RWs)*	Y	Y	Y	Y
Ground System *(Ground Station, Antennas, DDS)*	Y	Y	Y	Y
HGAS *(GCE, Gimbals)*	Y	Y	Y	Y
Power *(PSE, Solar Arrays, Battery)*	Y	Y	Y	Y
Propulsion	Y	Y	Y	Y
Mechanical	Y	Y	Y	Y
LPSC	Y	Y		
PCC	Y	Y		
SDN	Y	Y		
Thermal	Y	Y	Y	Y
Instrument	Y	Y	Y	Y

Table 3-5 Planned Component-Level Peer Reviews

3.3 SDO SYSTEM ENGINEERING LIFECYCLE ACTIVITIES

The SDO development effort will follow the following phased development approach in order to conceive and develop the mission implementation concept. This phased approach is continued as the various components of the system are developed and integrated into a comprehensive system, which is then tested, verified and operated, all according to the defined requirements, system architecture, and implementation approach.

3.3.1 Pre-Phase A

During the Pre-Phase A SDO lifecycle period, the SDO Science Definition Team (SDT) was assembled and chartered to investigate and define a set of science questions to be addressed by the SDO mission. In addition, in order to address these questions, the SDT defined the basic types of solar observations and data types needed to answer the defined science questions, as well as devising a proposed suite of generic instrument types that would satisfy the data types needed. The results of this study were assembled into the SDO Science Definition Team Report (NP-2001-12-410-GSFC). This report formed the basis for the SDO Announcement of Opportunity (AO) for solicitation of instrument proposals for the SDO science mission.

In addition, a number of NASA and industry studies were commissioned to investigate and propose preliminary concepts and proposals for the SDO spacecraft bus design in accordance with the recommendation of the SDO Science Definition Team report.

Pre-Phase A concept studies end with the selection of the SDO instruments, with Instrument and spacecraft investigation and preliminary analysis occurring in Phase A.

3.3.2 Phase A

During the Phase A lifecycle period, Preliminary Analysis of the SDO concept will be conducted. Table 3-6 summarizes the SDO Phase A plan and activities.

	Preliminary Analysis Phase A
Understanding the Objectives	- Understand and define Level 1 science requirements; Identify full and minimum mission reqs - 1st draft of Level 1 reqs for review at MDR - Validate Level 1 requirement and show flowdown to Level 2 requirements at MDR
Operations Concept Development	- Identify and define SDO Mission Phases - Complete preliminary draft version of SDO Operation Concept Document
Architecture & Design Development	- Review SDO Science Definition Team Report & previous concept studies - Identify key SDO design drivers & perform trade studies of various implementation design concepts - Define architecture design concept and balance with reqs and ops concept
Requirements Identification & Management	- Define draft Level 2 MRD reqs & demonstrate flowdown & traceability to Level 1 reqs at MDR - Detailed walkthrough of MRD Level 2 reqs traceability and assignment at SRR - Initial entry of MRD Level 2 reqs into DOORS database for mgmt and tracking - Define initial SDO Doc Tree, detailing subsystem reqs documentation structure & responsibility
Validation & Verification	- Perform initial trade studies and fold into initial system architecture design concept - Demonstrate MRD Level 2 reqs traceability to Level 1 reqs and to implementation design concept at SRR
Interfaces & ICDs	- Begin initial discussions across instrument and subsystem lines on interface design concepts as part of initial architecture design baseline effort - Identify proposed ICD documents within SDO Document Tree
Mission Environments	- Complete initial radiation environment assessment and document in draft radiation white paper - Begin ray trace analysis of initial design concept to further define component TID environment - Distribute contamination questionnaire to Instr, establish contamination working group, and complete draft contamination assessment - Define initial flight operational & test environments in Systems Verif & Envi Def document
Technical Resource Budget Tracking	- Establish formulation resource allocations as part of architecture design concept investigations - Baseline resource allocations at end of Phase A within SCR allocation margins - Bring resource allocations under CM at beginning of Phase B
Risk Management	- Establish Risk Management Plan & Procedures & identify, classify, & report initial risk items - Begin initial fault tree analysis and reliability block diagrams and use to optimize design concept
System Milestone Reviews	- Hold Mission Design Retreat (MDR) to review Level 1 reqs and initial design concept - Hold System Reqs retreat (SRR) for detailed walkthrough of Level 2 MRD reqs and demonstrate flowdown & traceability to Level 1 reqs - Hold SRR/SCR for external review team- acts as review milestone for progression Phase B
Configuration Management & Documentation	- Define SDO document tree and define subject, when due , and who responsible for each document
System Engineering Management Plan	- Complete draft SEMP and plans for Phase A definition of "single system design" concept - Update SEMP for Phase B activity plans to "design the right system"

Table 3-6 SDO Phase A System Engineering Activities

3.3.3 Phase B

During the Phase B lifecycle period, System Definition of the SDO concept will be conducted. Table 3-7 summarizes the SDO Phase B plan and activities.

	System Definition Phase B
Understanding the Objectives	- Level 1 Science Reqs competed & signed off by NASA HQ; Includes minimum mission reqs - Track any changes to Level 1 reqs (changes req NASA HQ approval)
Operations Concept Development	- Refine SDO Mission Phases definitions and SDO Operation Concept Document
Architecture & Design Development	- CM block diagram of SDO architecture design concept - Begin preliminary system and subsystem design process - Begin conceptual breadboard design process; use conceptual breadboards as initial testbeds and for initial interface testing across subsystems for risk reduction
Requirements Identification & Management	- Define draft Level 2 MRD reqs & demonstrate flowdown & traceability to Level 1 reqs at MDR - Detailed walkthrough of MRD Level 2 reqs traceability and assignment at SRR - Initial entry of MRD Level 2 reqs into DOORS database for mgmt and tracking - Define initial SDO Doc Tree, detailing subsystem reqs documentation structure & responsibility
Validation & Verification	- Update MRD Level 2 reqs with verification information and use process to check validity of reqs
Interfaces & ICDs	- Baseline and release initial documents and ICDs on SDO Document Tree
Mission Environments	- Complete more detailed radiation environment assessment and Observatory ray trace - Update contamination assessment and complete draft Contamination Control Plan - Begin evaluation and tracking of parts and materials for use in identified flight environment - Update flight operational & test environments in Systems Verif & Envi Def document
Technical Resource Budget Tracking	- Bring resource allocations under CM at beginning of Phase B within appropriate margins - Track and control resource allocations to complete Phase B within PDR margin allocations
Risk Management	- Complete initial FMEA of preliminary design concept and fold results back into design - Update fault tree analysis and reliability block diagrams & use to further optimize design concept - Ongoing identification, classification, & reporting of risk items per Risk Mgmt Plan & Procedures
System Milestone Reviews	- Hold subsystem peer reviews and PDRs to review Level 3 reqs and initial design concepts - Hold Mission PDR for external review team- acts as review milestone for progression Phase C
Configuration Management & Documentation	- Initiate CCB process to address changes to configured documents - Bring Level 1 Reqs, MRD Level 2 Reqs, and Level 3 Subsystem spec under CM
System Engineering Management Plan	- Update SEMP for Phase C Design activity plans to ensure system is “implemented right”

Table 3-7 SDO Phase B System Engineering Activities

3.3.4 Phase C

During the Phase C lifecycle period, System Design of the SDO concept will be conducted. Table 3-8 summarizes the SDO Phase C plan and activities.

	System Design Phase C
Understanding the Objectives	- Track any changes to Level 1 reqs (changes req NASA HQ approval) and flow down changes to lower level reqs
Operations Concept Development	- Complete SDO Mission Phases definitions and SDO Operation Concept Document and bring document under CM
Architecture & Design Development	- Begin ETU design and fabrication process; use ETU for design validation and for initial interface testing across subsystems for risk reduction
Requirements Identification & Management	- Track changes to Level 2 MRD and Level 3 reqs using DOORS database for reqs mgmt
Validation & Verification	- Begin effort to verify all reqs that identify analysis as verification method - Begin formulation, development and planning for Comprehensive Performance Test (CPT), used to validate reqs and system functionality and performance
Interfaces & ICDs	- Baseline and release component and lower level ICDs
Mission Environments	- Update and maintain environmental assessments and plans - Continue evaluation and tracking of parts and materials for use in identified flight environment - Update flight operational & test environments in Systems Verif & Envi Def document for use in subsystem and Observatory verification program
Technical Resource Budget Tracking	- Track and control resource allocations to complete Phase C within CDR margin allocations
Risk Management	- Complete initial FMEA of flight design concept and assess results - Update fault tree analysis and reliability block diagrams & use to evaluate design concept - Ongoing identification, classification, & reporting of risk items per Risk Mgmt Plan & Procedures
System Milestone Reviews	- Hold subsystem CDRs to review flight design concepts - Hold Mission CDR for external review team- acts as review milestone for progression Phase D
Configuration Management & Documentation	- Bring flight drawings and ICDs under CM
System Engineering Management Plan	- Update SEMP for Phase D Development activity plans to ensure flight system is properly tested and verified

Table 3-8 SDO Phase C System Engineering Activities

3.3.5 Phase D

During the Phase D lifecycle period, System Development and testing (verification) of the SDO concept will be conducted. Table 3-9 summarizes the SDO Phase D plan and activities.

	System Development Phase D
Understanding the Objectives	- Track any changes to Level 1 reqs (changes req NASA HQ approval)
Operations Concept Development	- Complete flight ops plans and flight ops procedures and perform mission simulations and testing
Architecture & Design Development	- Fabricate, test, verify, deliver and integrate flight components to the SDO Observatory for assembly and test - Establish and follow Work Order and PFR system in assembling and verifying Observatory
Requirements Identification & Management	- Utilize requirements database to track and ensure verification of all requirements through inspection, analysis, or testing
Validation & Verification	- Ensure full verification of all requirements through various phases of system development/integration and prior to system launch - Initial ongoing trending of Observatory functions through test process as tool in assessing Observatory operation and requirements verification
Interfaces & ICDs	- Verify interfaces through integration, test and verification process; address divergence from ICD interfaces
Mission Environments	- Perform environmental testing per environments defined in Systems Verif & Envi Def document in order to verify Observatory component and Observatory operation
Technical Resource Budget Tracking	- Track and control resource allocations to complete system development and allow launch of Observatory
Risk Management	- Ongoing identification, classification, & reporting of Risk Items per Risk Mgmt Plan & Procedures - Disposition and address all remaining risk items prior to Pre-Launch review; all items should either be closed or accepted with specific rationale noted
System Milestone Reviews	- Hold Test Readiness Reviews (TRRs) at all levels prior to testing - Hold Pre-Ship Reviews (PSRs) or System Acceptance Reviews (SARs) to ensure acceptability of end item - Hold Flight operations review (FOR) to review mission operations plans and concepts - Hold overall system Flight Readiness Review (FRR) to assure final technical readiness for launch - Hold Operations Readiness Review (ORR) to assure plans and resources in place to transition into an operational mode
Configuration Management & Documentation	- Continue to document and maintain any changes to systems documentation - Prepare archive of design and manufacturing documentation for use in I&T and post launch debugging and anomaly investigation
System Engineering Management Plan	- Update SEMP for Phase E/F Development activity plans to launch and operate the SDO system

Table 3-9 SDO Phase D System Engineering Activities

3.3.6 Phase E/F

During the Phase E/F lifecycle period, System Operation & Disposal of the SDO mission will be conducted. Table 3-10 summarizes the SDO Phase E plan and activities.

	System Operations & Disposal Phase E/F
Understanding the Objectives	- Track any changes to Level 1 reqs (changes req NASA HQ approval)
Operations Concept Development	- Ops concept document is superceded by Flight Ops plan (FOP) - Document any new operational constraints uncovered as part of operations process
Architecture & Design Development	- Utilize archive of design and manufacturing documentation for use in in-flight operations, anomaly investigation and system debugging
Requirements Identification & Management	
Validation & Verification	- Perform ongoing trending of Observatory functions as tool in assessing Observatory operation and mission performance
Interfaces & ICDs	- Utilize archive of ICD documentation for use in anomaly investigation and system debugging; Ground system ICD is still in use
Mission Environments	- Ongoing trending of Observatory performance in mission environments as tool in assessing Observatory operation and verifying prediction used (applicable to future missions)
Technical Resource Budget Tracking	- Track space and ground based resources that continue to have operations implications (onboard memory, ground data storage, ground line transmission resources, propellant usage, data capture statistics, etc)
Risk Management	- Risk management transfers to addressing future threats to observatory operations and is addressed by MOC staff
System Milestone Reviews	- Decommissioning Review prior to mission disposal
Configuration Management & Documentation	- CCB continues to track FSW updates and other changes to baseline configuration of Observatory or ground system
System Engineering Management Plan	

Table 3-10 SDO Phase E/F System Engineering Activities

4.0 COMMUNICATIONS

The systems engineering effort is distributed across many system elements that comprise the SDO Mission. Effective and timely communication is required in order to coordinate the various system elements together into a cohesive whole.

In order to coordinate the system engineering functions across the SDO subsystem elements, a variety of methods are employed to identify, track, and address system engineering functions throughout the SDO development effort

4.1 SDO MEETINGS

The following SDO meetings are held on a periodic basis to help coordinate and address SDO system engineering issues throughout the various levels of the project organization and across organizational lines.

4.1.1 System Engineering Team Coordination Meeting

The System Engineering Team will hold informal weekly coordination and planning meetings within the SDO system engineering organization. The purpose of this weekly meeting, planned for the beginning of the week, is to identify technical and organization areas that need to be addressed that week and to disseminate information among the systems team members. Ongoing issues and upcoming events will be priorities during this meeting, allowing the systems team to address issues on a timely basis as they arise. Topics identified during this meeting will often be selected to be addressed during the weekly project systems meeting or the instrument telecon. The Systems Team will create and utilize a prioritized list of topics in order to better allocate systems team resources to address various ongoing issues. The Deputy Project Manager, Observatory Manager, and Instrument Systems Manager attend and contribute to these meetings to ensure their valuable inputs in generating and assigning priorities.

4.1.2 Project System Meeting

The Systems team will lead a weekly project systems meeting for the SDO development team PDLs and their staff. The purpose of this meeting is to provide a weekly forum to address technical and developmental issues. The topic of the meeting will be announced in advance to allow the Systems team and PDLs to prepare for the topic at hand and to target those PDLs whose attendance is required. The weekly meeting topic may be a project-wide issue requiring attendance and participation of an authorized representative for each PDL or subsystem, or may a be a more specific targeted issue that may be relevant to only a subset of the SDO PDLs. The SDO System team may lead the meeting or may use the forum to allow one of the SDO subsystem teams to use the meeting as a platform to present any timely issues to the SDO team.

4.1.3 Project Senior Staff Meeting

The MSE and SEE (or their representatives) will participate in the weekly SDO Senior Staff meeting held by the SDO Project Manager. This weekly meeting acts as a coordination meeting between the Project Manger and his senior staff, of which the MSE and SEE are members. This meeting provides a vehicle by which the systems team coordinates ongoing issues and activities with the PM and senior staff, as well as providing a forum by which specific system engineering concerns and issues are raised to the project level for discussion and resolution.

4.1.4 Weekly Instrument Telecons

The systems team will plan and lead a weekly instrument technical telecon with the SDO Instrument development teams. Coordinated and led by the Instrument Systems

Accommodations Manager (ISAM), this telecon will act as a weekly call-in forum to address ongoing technical and accommodation issues between the GSFC SDO development team and the Instrument development teams. The ISAM will select a topic for each week's instrument telecon and notify the GSFC and instrument teams in advance so that the relevant PDLs and instrument team members can attend the weekly telecon.

4.1.5 Observatory Development Meeting

The systems team will participate in the weekly Observatory development meeting, which is held on a weekly basis and led by the SDO Observatory manager. The Observatory meeting coordinates technical and programmatic development issues for the SDO observatory and is a forum for focusing on and addressing a variety of development issues with the Observatory PDLs. PDLs report their weekly status to the Observatory manager, as well as raise development issues or concerns. Splinter meetings may be scheduled by the Observatory manager or systems team to further understand or help address issues raised in this meeting

4.1.6 Project Staff Meeting

The systems team will also attend and participate in the bi-weekly SDO staff meeting held by the SDO project. This weekly staff meeting is planned as a forum for the SDO Project Manager to disseminate programmatic direction to the project staff, as well as a forum for the project staff to report on pertinent status and raise issues (usually of a programmatic nature) to the SDO project team and Project Manager.

4.1.7 Resource Management Board (RMB)

As part of its charter to oversee and control the SDO technical resources, the SDO Systems Team will employ and lead a Resource Management Board (RMB) to assess the status of SDO technical resources and review and advise the Configuration Control Board (CCB) in the event of all Configuration Change Requests (CCRs) for changes in resource allocations.

The RMB will act in an advisory capacity to review all resource allocation CCRs and recommend to the CCB how the CCR should be dispositioned, with the goal being to streamline the resource allocation CCR process. The SSE shall act as the informal chair and leader of the RMB, delegating his responsibilities to another member of the systems or project management team in his absence. It is the responsibility of the RMB chair to research and evaluate all allocation CCRs in the context of the overall system margin as well as the current lifecycle phase (and appropriate margin required).

The RMB will meet as needed after receipt of any allocation CCRs and prior to the actual CCB in question.

4.1.8 Tiger Teams

At various times throughout the system engineering lifecycle, the systems team will lead or participate in a variety of short, focused technical or development efforts directed to address a specific issue of concern. The scope and duration of these tiger teams will vary depending on the issue at hand.

4.2 REPORTING AND STATUSING

In addition to the various SDO meetings, the systems team will rely on a variety of communication methods for reporting and statusing to ensure the configuration management of the SDO implementation design and to ensure that issues are reported and acted upon in a timely manner.

4.2.1 Action Item System

The SDO system team will employ an action item reporting and statusing system to address and close issues associated with the SDO development process.

Action items can be entered into the system via a variety of avenues: Actions from external reviews, peer reviews, retreats, status meetings, staff meetings, emails, etc. Actions are entered into the system and collated by the CM office for review by the systems team. The CM office and the systems team identify the action, additional description or clarification of the action item, who initiated the action, who the action is assigned to, when the action was written and at what review (if applicable), who reviews the action items response, when it is due, and the current status of the action item.

The system team meets with the CM office on a weekly basis to review and status all action items, releasing an updated action item list to the project team roughly every week. Action items are assigned to relevant subsystems, who are then to investigate and disposition, and submit the action item for closure. As action items are statused by the project team, they are reviewed and updated by the systems team and the CM office. In order for an action to be closed, specific information must be provided or referenced (i.e. a report, review slide number, detailed description, etc) that can be linked with the action and later retrieved for documentation purposes.

Once an action item is submitted for closure, the system team reviews the response, then directs the action to the appropriate subsystem discipline for review. When the system team and appropriate subsystem personnel agree that an action is ready to enter the closure process, the action is then forwarded to the action item initiator for review. This provides the individual who initiated the action item an opportunity as to whether the closure response meets the intent of the action item. If not, further clarification of the action item query is added and the action is re-entered into the system. If the initiator agrees with the closure information, the action is then closed and the closure information filed with the CM office.

4.2.2 Risk Management System

In order to identify, assess, and track SDO development risk items, the SDO Systems Engineering Team will utilize the SDO Risk Management process detailed in the SDO Project Continuous Risk Management Plan (Document # 464-SA-PLAN-0003).

4.2.3 Configuration Management System

In order to establish and maintain configuration control of all aspects of the SDO implementation design, the SDO systems team will follow the guidelines directed in the SDO Configuration Management Procedure (document # 464-PG-1410.2.1)

4.3 KNOWLEDGE TRANSFER

In addition to the various SDO meetings, the systems team will rely on a variety of communication methods for reporting and statusing to ensure the configuration management of the SDO implementation design and to ensure that issues are reported and acted upon in a timely manner.

4.3.1 Lessons Learned

In order to draw upon the experience garnered from previous NASA missions and development efforts, the SDO development team will utilize the GSFC on-line Lessons-Learned Information System (LLIS) (*http://llis.gsfc.nasa.gov/)* to determine if there are applicable lessons relating to the development of the SDO mission and its components. The development team will report on any applicable results as part of the development peer review process

4.3.2 Knowledge Capture

In order to capture the processes, philosophy and development documentation and work products developed as part of the SDO development effort, the SDO Systems team will produce an electronic tool in a data CD medium (or DVD medium, depending of the volume of data included). This reference CD will address the SDO Mission as a sample case study in mission development and will capture SDO development documentation in a manner that can be searched and retrieved in a variety of methods: By organization or responsibility (WHO), by the subject or nature of the work (WHAT), or by schedule or development flow timeline (WHEN). It is the intent that all SDO configured documents and the majority of SDO work products will be archived for inclusion in this reference tool. In addition to acting a resource for future mission development, it will act as a valuable tool the flight operations team (FOT) during mission operations.

4.3.3 SDO Project Document Access

The SDO project will maintain an ongoing website for the purpose of information archiving and providing access to SDO documentation. SDO documents under SDO Project CM will be available via the SDO MIS (Mission Information Site) project website, as well as archived work products for reference and informational purposes. The SDO MIS URL is *https://sdomis.gsfc.nasa.gov* and website access information can be provided by contacting the SDO project office

5.0 CONFIGURATION MANAGEMENT AND DOCUMENTATION

There are two primary categories of SDO core documentation and document management: CM controlled documents and CM released documents (archived work products)

5.1 CONTROLLED DOCUMENTS

All SDO controlled documents shall be maintained in accordance with the guidelines directed in the SDO Configuration Management Procedure (document # 464-PG-1410.2.1). Controlled documents are those that define the SDO requirements, implementation design, and operations concept. All SDO CM documentation is contained in the SDO Document Tree and adjunct document list (See Appendix B), with the current version maintained online on the SDO MIS (Mission Information Site) (*https://sdomis.gsfc.nasa.gov*)

5.1.1 Requirements

All SDO requirements documents shall be placed under the SDO CM system as controlled documents. This includes the Level 1 requirements in the LWS Program Plan appendix, the Level 2 requirements in the SDO MRD and other crosscutting Level 2 requirements documents (MAR, etc), the Level 3 requirements documents in the SDO subsystem requirements/specification documents, and the Level 4 and below reqs addressed in lower level component requirements/specification documents. All requirements shall be entered into the DOORs requirements tracking database to assist in linking, managing and tracking requirements. However, the DOORs database is used only as a requirements traceability tool to help trace effects of any requirements changes on SDO configured requirements documents. Note that the Level 1 requirements are ultimately controlled at the LWS Program and NASA Headquarters levels and cannot be changed without concurrence and signed agreement between these two organizations. Any changes to Level 1 requirements must first be approved by the SDO Project CCB, then passed on to the LWS Program and NASA Headquarters for approval by their modification and signoff in the LWS Program Plan appendix section.

5.1.2 Implementation Design

Work design products which define the SDO implementation design and are used in its manufacturing and testing shall be placed under the SDO CM system as controlled documents. This included implementation specifications, design drawings, and similar materials. All subsystem ICDs dealing with external subsystem interfaces are also controlled documents and shall be governed under the SDO CM procedures. Major SDO technical resources and budgets (mass power, data capture budget, etc) shall be captured and governed under the CM procedures as well.

5.1.3 Operations Concept

All plans and procedures detailing the operational concept of the SDO mission are designated as CM controlled documents and shall be governed by the SDO CM procedures. This includes the Ops concept document and associated lower level operations concept documents. In addition, all operation procedures and ground databases will be baselined at an appropriate time prior to launch and thereafter governed by the CM process in order to maintain configuration control and ensure SDO observatory safety.

5.2 RELEASED DOCUMENTS

The SDO CM office shall also accept and archive a variety of SDO work products for reference and informational purposes. While not controlled under the SDO CM procedures, these archived work products provide further valuable information into the SDO design and design process. The CM office provides a central location for the archiving, as well as easy access and distribution of these documents to the entire SDO team. Document that are included in this type of document category include the following: design data packages (block diagrams, etc), design review packages (converted to PDF format for archiving and easy accessibility), trade study results, white papers, SDO Action Item database, SDO Risk management list, etc. See Section 4.3.3 for more information on the use of the SDO project website for SDO project documentation access

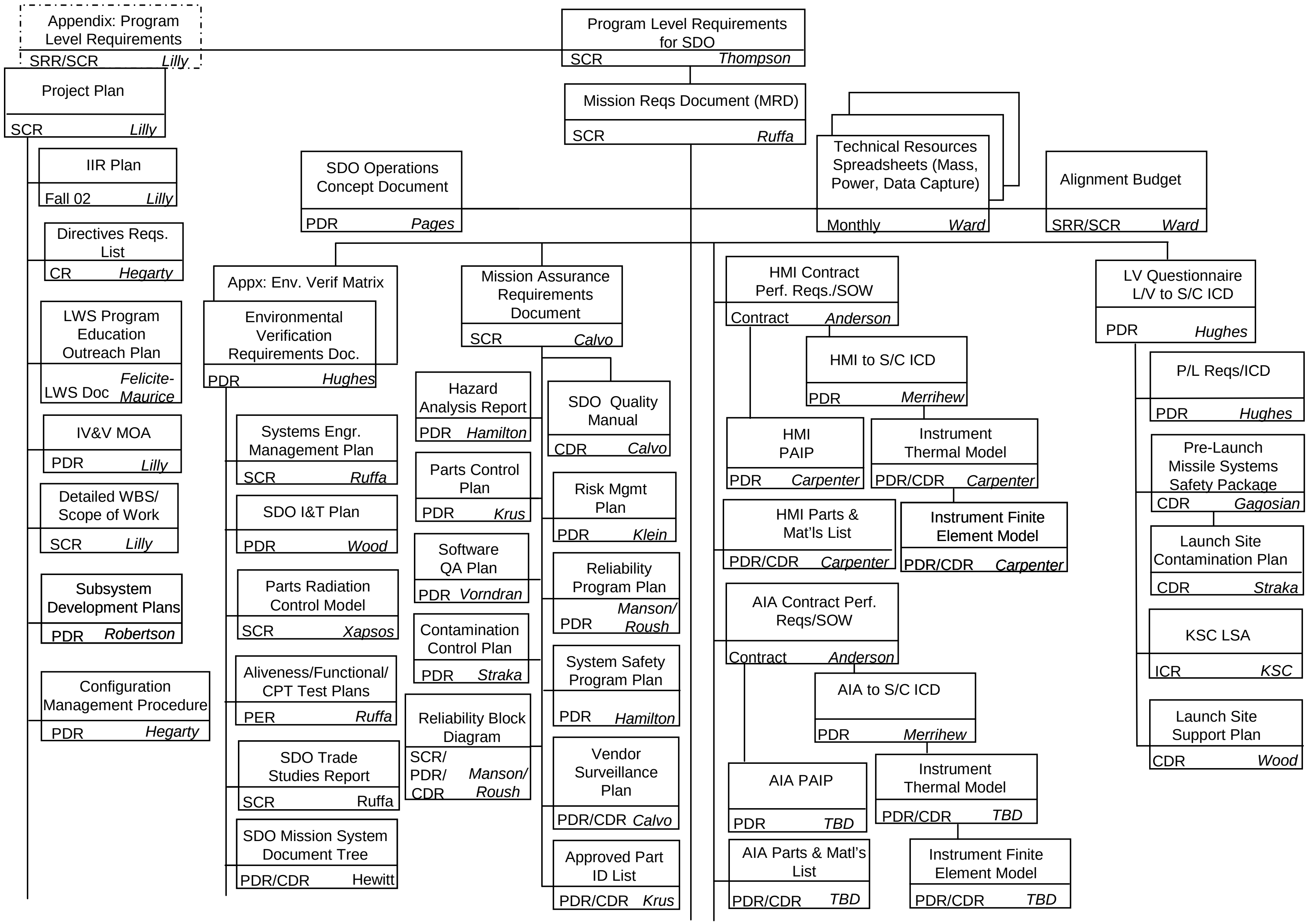
Appendix A. Abbreviations and Acronyms

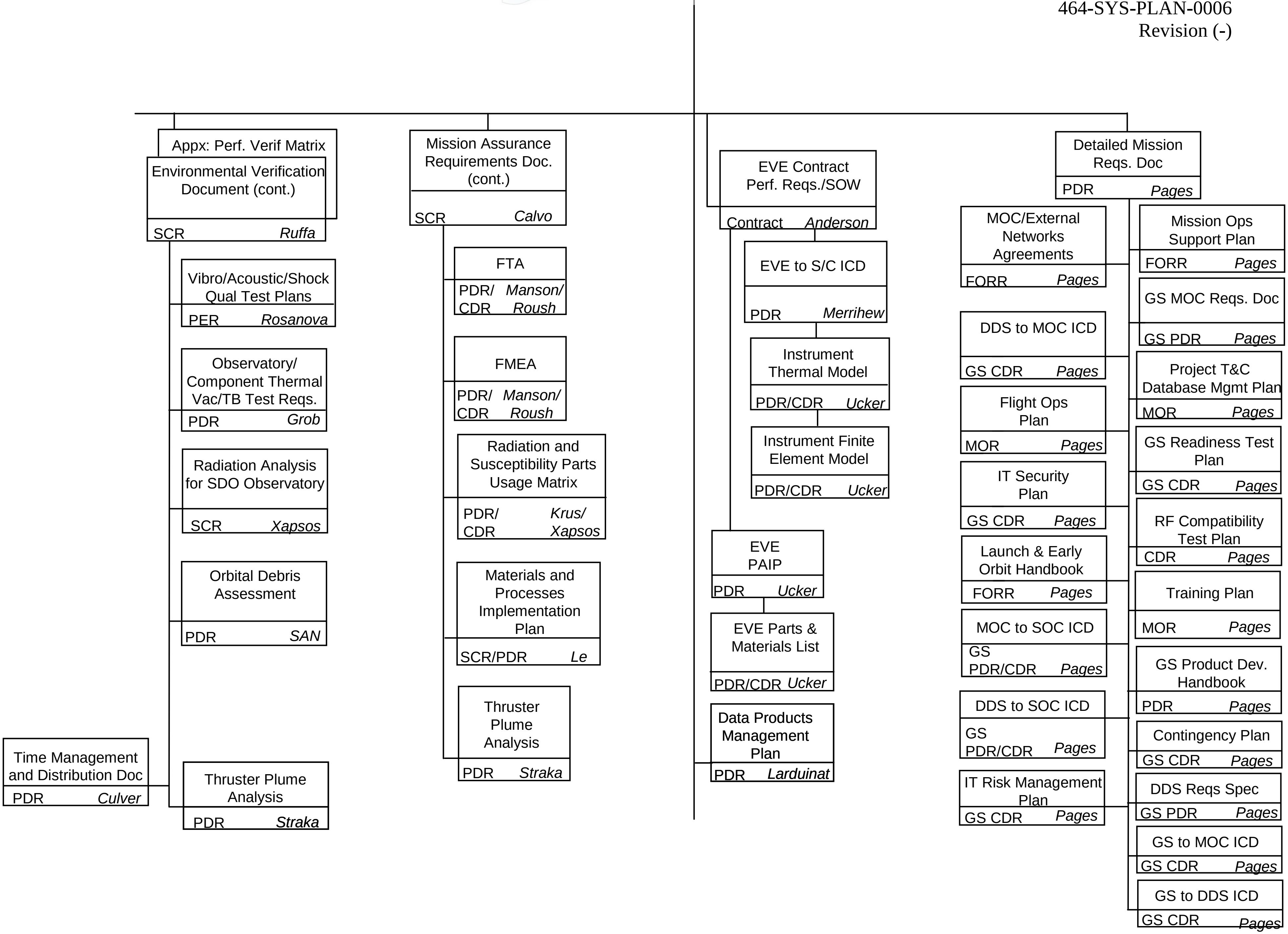
Abbreviation/ Acronym	DEFINITION
AIA	Atmospheric Imaging Assembly
CDR	Critical Design Review
CLE	Contamination Lead Engineer
DDS	Data Distribution System
EELV	Evolved Expendable Launch Vehicle
EVE	Extreme Ultraviolet Variability Experiment
FMEA	Failure Modes and Effects Analysis
FOP	Flight Operations Plan
FOT	Flight Operations Team
FTA	Fault Tree Analysis
GN&C	Guidance, Navigation, and Control
GNCSE	GN&C Systems Engineer
GSE	Ground Support Equipment
GTO	Geosynchronous Transfer Orbit
HMI	Helioseismic and Magnetic Imager
ICD	Interface Control Document
ISAM	Instrument Systems Accommodations Manager
ISM	Instrument Systems Manager
KSC	Kennedy Space Center
LASP	Laboratory for Atmospheric and Space Physics
LMSAL	Lockheed Martin Solar & Astrophysics Laboratory
LWS	Living with a Star
ME	Materials Engineer
MOC	Missions Operations Center
MSE	Mission Systems Engineer
OSE	Operations Systems Engineer
PDL	Product Development Lead
PDR	Preliminary Design Review
PE	Parts Engineer
RBD	Reliability Block Diagram
RFA	Request for Action
RLE	Radiation Lead Engineer
RMB	Resource Management Board
RTT	Requirements Traceability and Tracking Lead
SCR	System Concept review
SDE	Systems Development Engineer
SDO	Solar Dynamic Observatory
SDT	Science Definition Team Report
SEMP	Systems Engineering Management Plan
SOC	Science Operation Center
SRE	Systems Reliability Engineer
SRR	System Requirements Review
SSE	Spacecraft Systems Engineer
SWSE	Software Systems Engineer

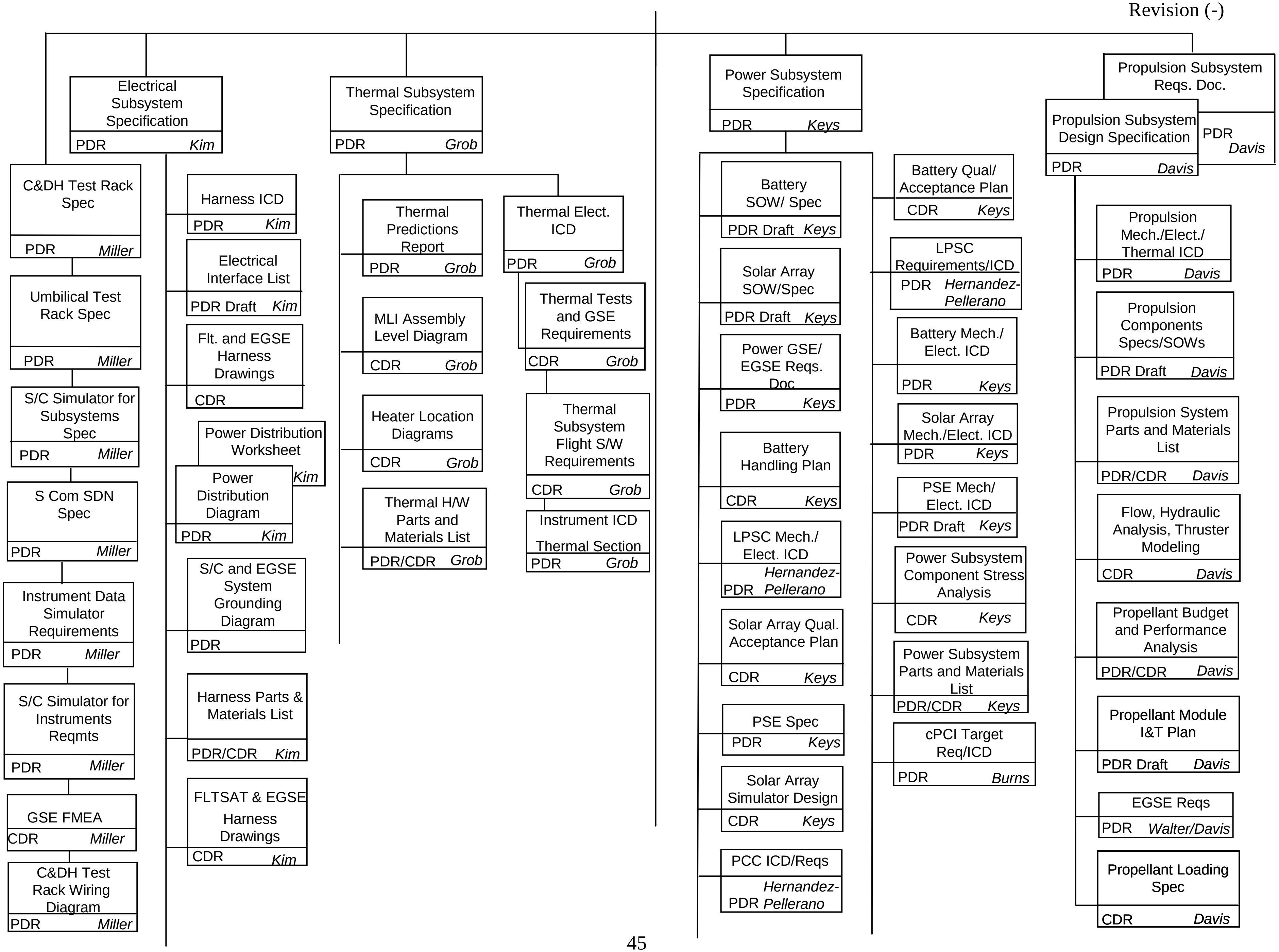
Appendix B. SDO Document Tree

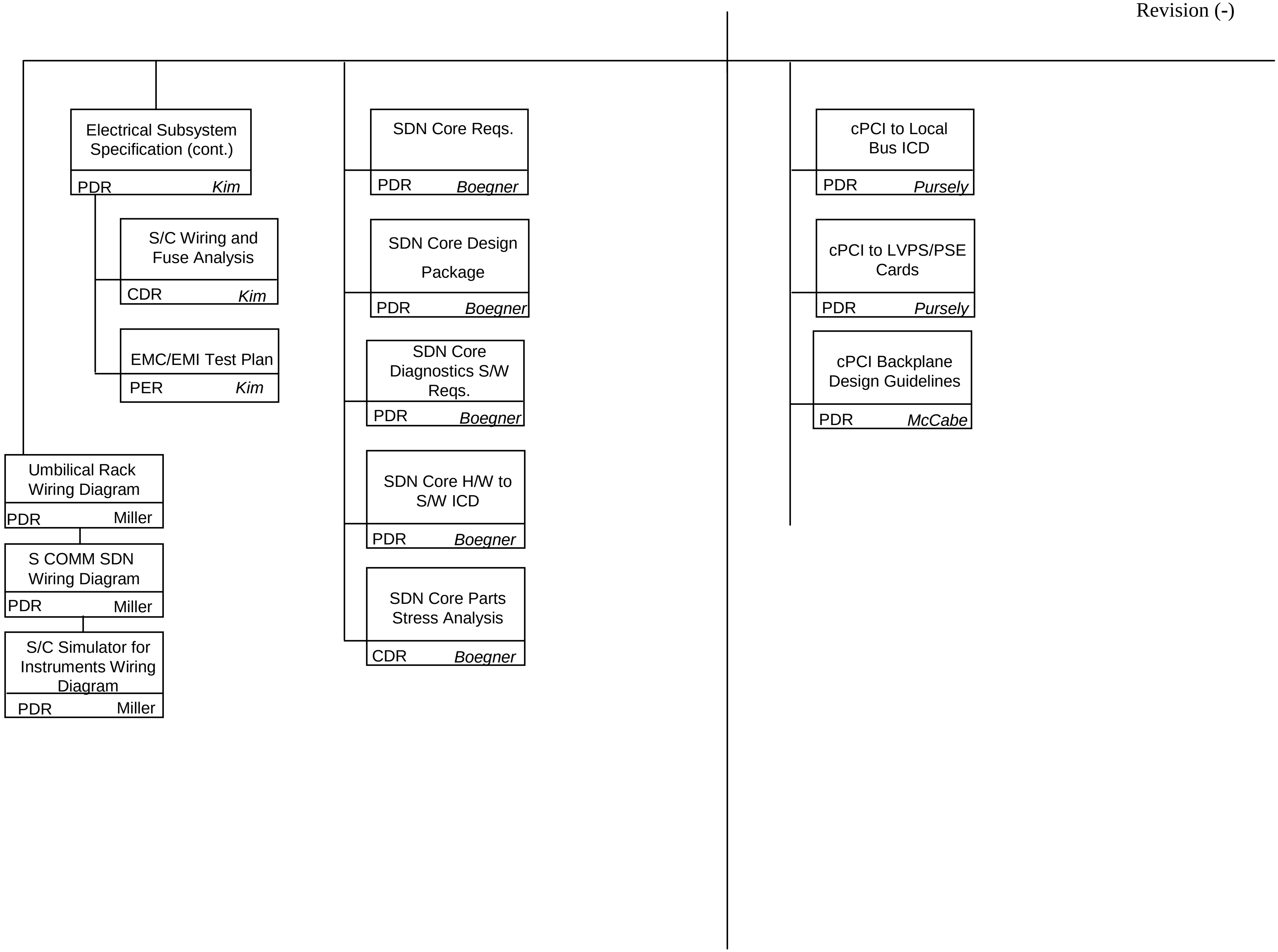
The following pages include the SDO document tree, which has been included in the SEMP for reference only. For the actual latest version of the SDO document tree, go to the SDO MIS (*https://sdomis.gsfc.nasa.gov*)

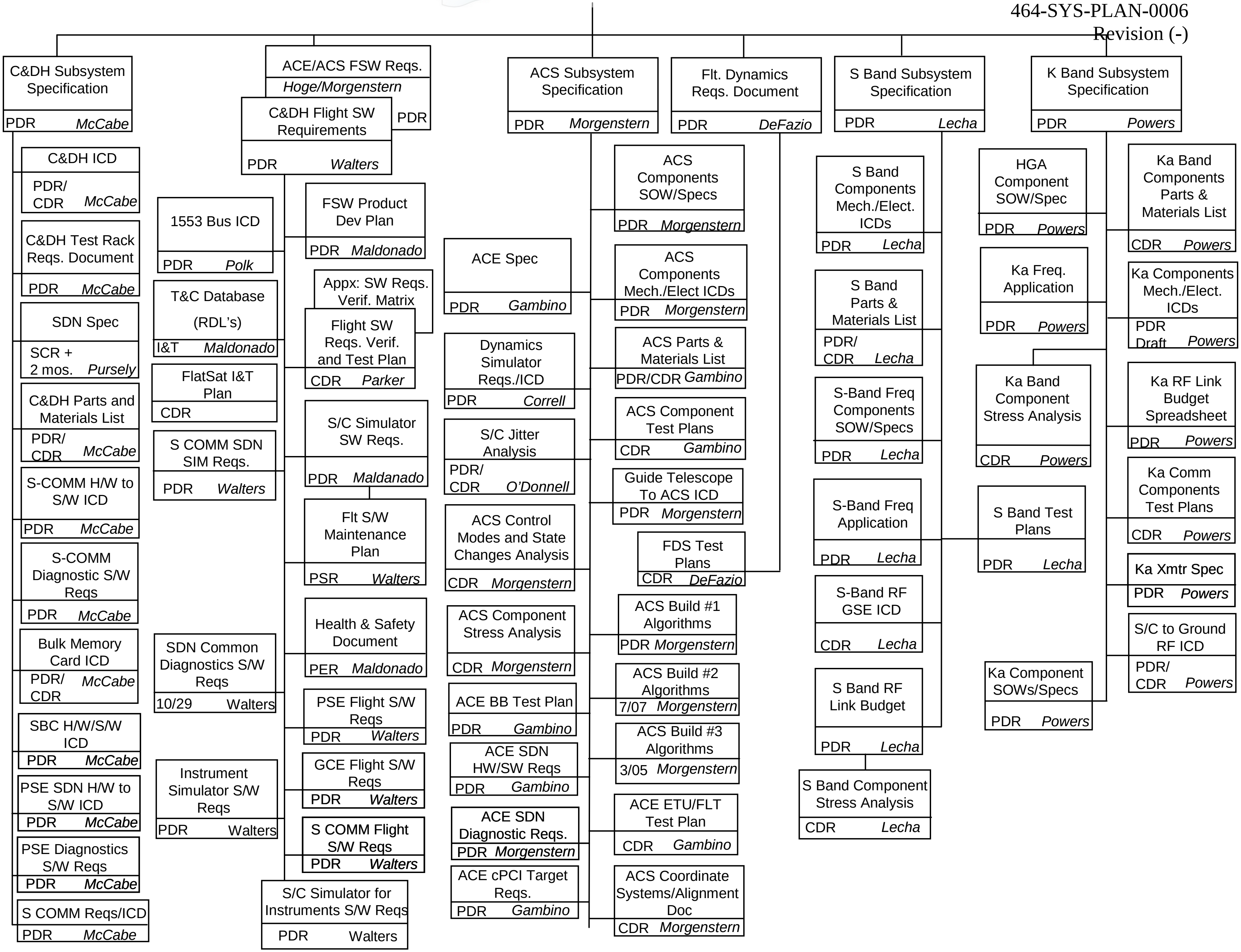
SDO MISSION SYSTEM DOCUMENTATION TREE – 464-PROJ-MGMT-0007

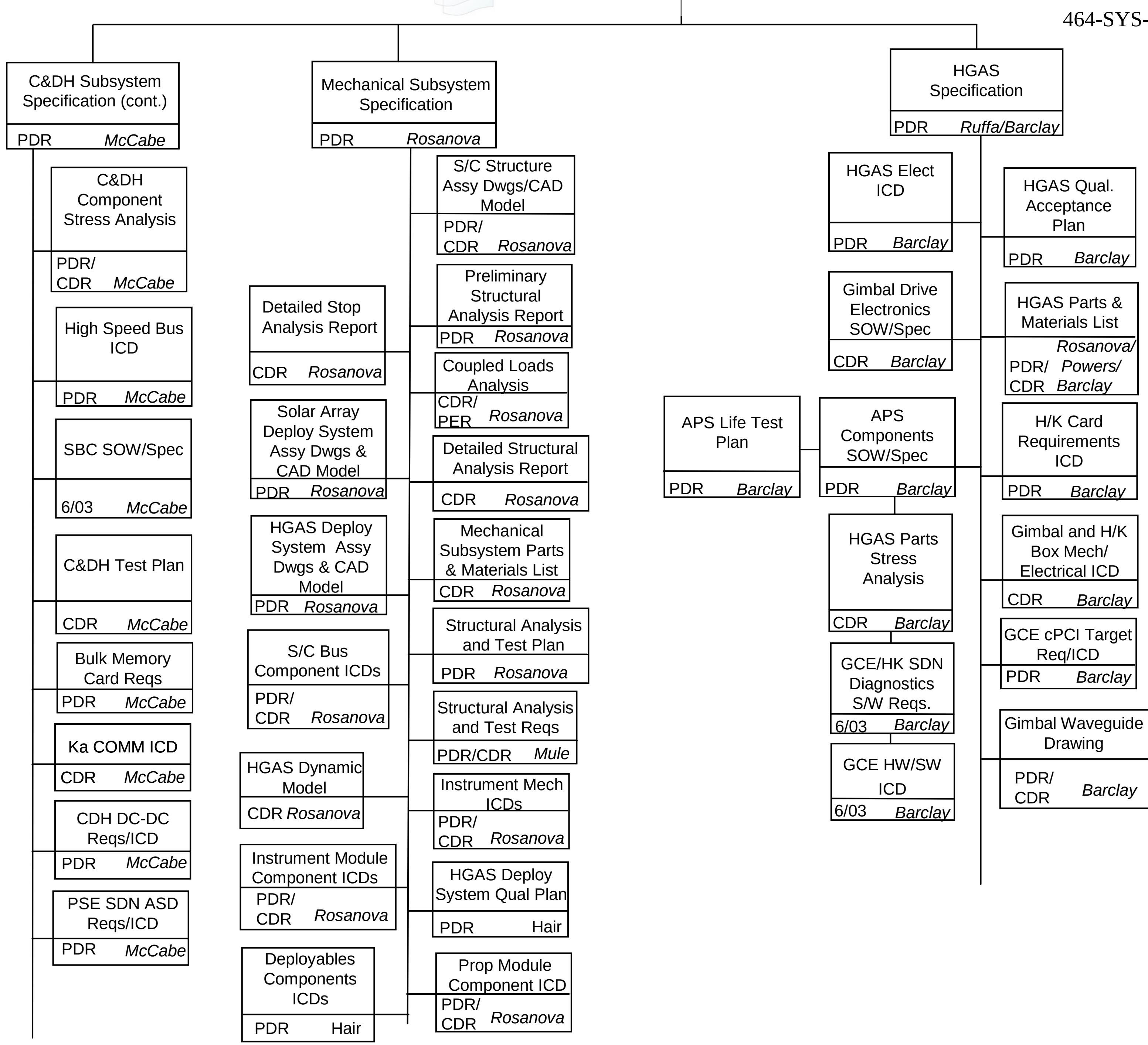



Appx: Perf. Verif Matrix
Environmental Verification Document (cont.)
SCR Ruffa
Vibro/Acoustic/Shock Qual Test Plans
PER Rosanova
Observatory/ Component Thermal Vac/TB Test Reqs.
PDR Grob
Radiation Analysis for SDO Observatory
SCR Xapsos
Orbital Debris Assessment
PDR SAN
Time Management and Distribution Doc
PDR Culver
Thruster Plume Analysis
PDR Straka
Mission Assurance Requirements Doc. (cont.)
SCR Calvo
FTA
PDR/ CDR Manson/ Roush
FMEA
PDR/ CDR Manson/ Roush
Radiation and Susceptibility Parts Usage Matrix
PDR/ CDR Krus/ Xapsos
Materials and Processes Implementation Plan
SCR/PDR Le
Thruster Plume Analysis
PDR Straka
EVE Contract Perf. Reqs./SOW
Contract Anderson
EVE to S/C ICD
PDR Merrihew
Instrument Thermal Model
PDR/CDR Ucker
Instrument Finite Element Model
PDR/CDR Ucker
EVE PAIP
PDR Ucker
EVE Parts & Materials List
PDR/CDR Ucker
Data Products Management Plan
PDR Larduinat
Detailed Mission Reqs. Doc
PDR Pages
MOC/External Networks Agreements
FORR Pages
DDS to MOC ICD
GS CDR Pages
Flight Ops Plan
MOR Pages
IT Security Plan
GS CDR Pages
Launch & Early Orbit Handbook
FORR Pages
MOC to SOC ICD
GS PDR/CDR Pages
DDS to SOC ICD
GS PDR/CDR Pages
IT Risk Management Plan
GS CDR Pages
Mission Ops Support Plan
FORR Pages
GS MOC Reqs. Doc
GS PDR Pages
Project T&C Database Mgmt Plan
MOR Pages
GS Readiness Test Plan
GS CDR Pages
RF Compatibility Test Plan
CDR Pages
Training Plan
MOR Pages
GS Product Dev. Handbook
PDR Pages
Contingency Plan
GS CDR Pages
DDS Reqs Spec
GS PDR Pages
GS to MOC ICD
GS CDR Pages
GS to DDS ICD
GS CDR Pages


Electrical Subsystem Specification PDR Kim
Thermal Subsystem Specification PDR Grob
Power Subsystem Specification PDR Keys
Propulsion Subsystem Reqs. Doc. PDR Davis
Propulsion Subsystem Design Specification PDR Davis
C&DH Test Rack Spec PDR Miller
Umbilical Test Rack Spec PDR Miller
S/C Simulator for Subsystems Spec PDR Miller
S Com SDN Spec PDR Miller
Instrument Data Simulator Requirements PDR Miller
S/C Simulator for Instruments Reqmts PDR Miller
GSE FMEA CDR Miller
C&DH Test Rack Wiring Diagram PDR Miller
Harness ICD PDR Kim
Electrical Interface List PDR Draft Kim
Flt. and EGSE Harness Drawings CDR
Power Distribution Worksheet Kim
Power Distribution Diagram PDR Kim
S/C and EGSE System Grounding Diagram PDR
Harness Parts & Materials List PDR/CDR Kim
FLTSAT & EGSE Harness Drawings CDR Kim
Thermal Predictions Report PDR Grob
MLI Assembly Level Diagram CDR Grob
Heater Location Diagrams CDR Grob
Thermal H/W Parts and Materials List PDR/CDR Grob
Thermal Elect. ICD PDR Grob
Thermal Tests and GSE Requirements CDR Grob
Thermal Subsystem Flight S/W Requirements CDR Grob
Instrument ICD Thermal Section PDR Grob
Battery SOW/ Spec PDR Draft Keys
Solar Array SOW/Spec PDR Draft Keys
Power GSE/ EGSE Reqs. Doc PDR Keys
Battery Handling Plan CDR Keys
LPSC Mech./ Elect. ICD PDR Hernandez-Pellerano
Solar Array Qual. Acceptance Plan CDR Keys
PSE Spec PDR Keys
Solar Array Simulator Design CDR Keys
PCC ICD/Reqs PDR Hernandez-Pellerano
Battery Qual/ Acceptance Plan CDR Keys
LPSC Requirements/ICD PDR Hernandez-Pellerano
Battery Mech./ Elect. ICD PDR Keys
Solar Array Mech./Elect. ICD PDR Keys
PSE Mech/ Elect. ICD PDR Draft Keys
Power Subsystem Component Stress Analysis CDR Keys
Power Subsystem Parts and Materials List PDR/CDR Keys
cPCI Target Req/ICD PDR Burns
Propulsion Mech./Elect./ Thermal ICD PDR Davis
Propulsion Components Specs/SOWs PDR Draft Davis
Propulsion System Parts and Materials List PDR/CDR Davis
Flow, Hydraulic Analysis, Thruster Modeling CDR Davis
Propellant Budget and Performance Analysis PDR/CDR Davis
Propellant Module I&T Plan PDR Draft Davis
EGSE Reqs PDR Walter/Davis
Propellant Loading Spec CDR Davis


Electrical Subsystem Specification (cont.)
PDR Kim
S/C Wiring and Fuse Analysis
CDR Kim
EMC/EMI Test Plan
PER Kim
Umbilical Rack Wiring Diagram
PDR Miller
S COMM SDN Wiring Diagram
PDR Miller
S/C Simulator for Instruments Wiring Diagram
PDR Miller
SDN Core Reqs.
PDR Boegner
SDN Core Design Package
PDR Boegner
SDN Core Diagnostics S/W Reqs.
PDR Boegner
SDN Core H/W to S/W ICD
PDR Boegner
SDN Core Parts Stress Analysis
CDR Boegner
cPCI to Local Bus ICD
PDR Pursely
cPCI to LVPS/PSE Cards
PDR Pursely
cPCI Backplane Design Guidelines
PDR McCabe


C&DH Subsystem Specification
PDR McCabe
C&DH ICD
PDR/ CDR McCabe
C&DH Test Rack Reqs. Document
PDR McCabe
SDN Spec
SCR + 2 mos. Pursely
C&DH Parts and Materials List
PDR/ CDR McCabe
S-COMM H/W to S/W ICD
PDR McCabe
S-COMM Diagnostic S/W Reqs
PDR McCabe
Bulk Memory Card ICD
PDR/ CDR McCabe
SBC H/W/S/W ICD
PDR McCabe
PSE SDN H/W to S/W ICD
PDR McCabe
PSE Diagnostics S/W Reqs
PDR McCabe
S COMM Reqs/ICD
PDR McCabe
ACE/ACS FSW Reqs.
Hoge/Morgenstern
PDR
C&DH Flight SW Requirements
PDR Walters
1553 Bus ICD
PDR Polk
T&C Database (RDL's)
I&T Maldonado
FlatSat I&T Plan
CDR
S COMM SDN SIM Reqs.
PDR Walters
SDN Common Diagnostics S/W Reqs
10/29 Walters
Instrument Simulator S/W Reqs
PDR Walters
FSW Product Dev Plan
PDR Maldonado
Appx: SW Reqs. Verif. Matrix
Flight SW Reqs. Verif. and Test Plan
CDR Parker
S/C Simulator SW Reqs.
PDR Maldanado
Flt S/W Maintenance Plan
PSR Walters
Health & Safety Document
PER Maldonado
PSE Flight S/W Reqs
PDR Walters
GCE Flight S/W Reqs
PDR Walters
S COMM Flight S/W Reqs
PDR Walters
S/C Simulator for Instruments S/W Reqs
PDR Walters
ACS Subsystem Specification
PDR Morgenstern
ACE Spec
PDR Gambino
Dynamics Simulator Reqs./ICD
PDR Correll
S/C Jitter Analysis
PDR/ CDR O'Donnell
ACS Control Modes and State Changes Analysis
CDR Morgenstern
ACS Component Stress Analysis
CDR Morgenstern
ACE BB Test Plan
PDR Gambino
ACE SDN HW/SW Reqs
PDR Gambino
ACE SDN Diagnostic Reqs.
PDR Morgenstern
ACE cPCI Target Reqs.
PDR Gambino
ACS Components SOW/Specs
PDR Morgenstern
ACS Components Mech./Elect ICDs
PDR Morgenstern
ACS Parts & Materials List
PDR/CDR Gambino
ACS Component Test Plans
CDR Gambino
Guide Telescope To ACS ICD
PDR Morgenstern
ACS Build #1 Algorithms
PDR Morgenstern
ACS Build #2 Algorithms
7/07 Morgenstern
ACS Build #3 Algorithms
3/05 Morgenstern
ACE ETU/FLT Test Plan
CDR Gambino
ACS Coordinate Systems/Alignment Doc
CDR Morgenstern
Flt. Dynamics Reqs. Document
PDR DeFazio
FDS Test Plans
CDR DeFazio
S Band Subsystem Specification
PDR Lecha
S Band Components Mech./Elect. ICDs
PDR Lecha
S Band Parts & Materials List
PDR/ CDR Lecha
S-Band Freq Components SOW/Specs
PDR Lecha
S-Band Freq Application
PDR Lecha
S-Band RF GSE ICD
CDR Lecha
S Band RF Link Budget
PDR Lecha
S Band Component Stress Analysis
CDR Lecha
HGA Component SOW/Spec
PDR Powers
Ka Freq. Application
PDR Powers
Ka Band Component Stress Analysis
CDR Powers
S Band Test Plans
PDR Lecha
Ka Component SOWs/Specs
PDR Powers
K Band Subsystem Specification
PDR Powers
Ka Band Components Parts & Materials List
CDR Powers
Ka Components Mech./Elect. ICDs
PDR Draft Powers
Ka RF Link Budget Spreadsheet
PDR Powers
Ka Comm Components Test Plans
CDR Powers
Ka Xmtr Spec
PDR Powers
S/C to Ground RF ICD
PDR/ CDR Powers


C&DH Subsystem Specification (cont.)
PDR McCabe
C&DH Component Stress Analysis
PDR/ CDR McCabe
High Speed Bus ICD
PDR McCabe
SBC SOW/Spec
6/03 McCabe
C&DH Test Plan
CDR McCabe
Bulk Memory Card Reqs
PDR McCabe
Ka COMM ICD
CDR McCabe
CDH DC-DC Reqs/ICD
PDR McCabe
PSE SDN ASD Reqs/ICD
PDR McCabe
Mechanical Subsystem Specification
PDR Rosanova
Detailed Stop Analysis Report
CDR Rosanova
Solar Array Deploy System Assy Dwgs & CAD Model
PDR Rosanova
HGAS Deploy System Assy Dwgs & CAD Model
PDR Rosanova
S/C Bus Component ICDs
PDR/ CDR Rosanova
HGAS Dynamic Model
CDR Rosanova
Instrument Module Component ICDs
PDR/ CDR Rosanova
Deployables Components ICDs
PDR Hair
S/C Structure Assy Dwgs/CAD Model
PDR/ CDR Rosanova
Preliminary Structural Analysis Report
PDR Rosanova
Coupled Loads Analysis
CDR/ PER Rosanova
Detailed Structural Analysis Report
CDR Rosanova
Mechanical Subsystem Parts & Materials List
CDR Rosanova
Structural Analysis and Test Plan
PDR Rosanova
Structural Analysis and Test Reqs
PDR/CDR Mule
Instrument Mech ICDs
PDR/ CDR Rosanova
HGAS Deploy System Qual Plan
PDR Hair
Prop Module Component ICD
PDR/ CDR Rosanova
HGAS Specification
PDR Ruffa/Barclay
APS Life Test Plan
PDR Barclay
HGAS Elect ICD
PDR Barclay
Gimbal Drive Electronics SOW/Spec
CDR Barclay
APS Components SOW/Spec
PDR Barclay
HGAS Parts Stress Analysis
CDR Barclay
GCE/HK SDN Diagnostics S/W Reqs.
6/03 Barclay
GCE HW/SW ICD
6/03 Barclay
HGAS Qual. Acceptance Plan
PDR Barclay
HGAS Parts & Materials List
PDR/ CDR Rosanova/ Powers/ Barclay
H/K Card Requirements ICD
PDR Barclay
Gimbal and H/K Box Mech/ Electrical ICD
CDR Barclay
GCE cPCI Target Req/ICD
PDR Barclay
Gimbal Waveguide Drawing
PDR/ CDR Barclay

Appendix C. SDO SRR/SCR Goals, Objectives, and Criteria

Note: Objectives and success criteria based on guidelines compiled from the NASA Systems Engineering Handbook, Space Science Enterprise Management Handbook, and Code 300 Review Guidelines.

SRR/SCR Objectives

- Demonstrate that the system requirements are clearly defined and reflect mission objectives
    - Requirements traceability from Level 1 Mission Requirements to lower level requirements

- Demonstrate that the Mission architecture/design/operations concept is acceptable, i.e. system fulfills mission objectives and can be built within the project constraints
    - Functional requirements and system implementation derived from top-level mission requirements, with clear requirements flow down and allocation to specific mission subsystems
    - Major trade studies completed and results utilized to ensure the best overall system approach within project constraints
    - Technology risks identified, as well as plans to mitigate risks
    - Refined cost, schedule and personnel resource estimates presented

- Demonstrate that a preliminary development flow and preliminary product verification program are defined
    - Overall system verification and validation approach defined
    - End item acceptance criteria established

- Demonstrate mission requirements, architecture/design, and operations concept is developed and documented at a level sufficient to proceed into preliminary design

SRR/SCR Success Criteria

1) Will the top-level system concept design meet the system requirements, satisfy the mission objectives, and address mission operational needs?
2) Have all the system level requirements been allocated to one or more lower levels?
3) Have all major trades studies been clearly identified and their results presented? Are the design implementation decisions supported by the trade study results?
4) Have the major design issues for the system and subsystems been clearly identified? Have risk mitigation plans been identified for all major risk areas?
5) Have new technology development items been identified, along with a verification of TRL 5 status at this review and a clear plan for TRL 6 by PDR? Have risk mitigation plans been identified for all new technology areas?
6) Have plans been identified and established to control the development and design process (internal and external reviews, peer reviews, CM, etc)
7) Is a preliminary verification/validation concept defined that can allow preliminary design to proceed (GSE design, I&T flow/schedule)? Is the minimum end item product performance documented in either the requirements or acceptance criteria?

8) Are the upper levels of the product breakdown structure (PBS) clearly defined, with major flight and ground hardware elements identified?
9) Can the top-level system concept design selected be built within cost constraints and within identified schedule? Are the cost and schedule estimates valid in view of the system requirements and selected architecture?
10) Is there a draft project plan in place governing the overall mission development effort? Is there sufficient information to support the programmatic cost and schedule efforts? Have life cycle costs for the mission been developed and presented (through Phase E, including science data products and archiving).
11) Are letters of agreement in place clearly documenting collaborations with all non-NASA partners (domestic and international)?
12) Has a draft project education and public outreach plan been formulated and presented?
13) Is an Environmental Assessment (EA) or Environmental Impact Statement (EIS) required, and is a draft Environmental Impact Plan required and in place?

Instrument and Subsystem Presentation Guidelines

Where applicable, all instrument and subsystem presentations should include the following information:

1. Requirements:
   - Level 2&3 plus major derived reqs; reqs traceability
2. Concept Details:
   - Overall concept (should include block diagrams/sketches)
   - Ops Concept
3. Trades studies
   - Results of trades
4. Technical resources
   - Mass, power, pointing, data completeness, or any other budgets applicable to that subsystem
5. Heritage & qualification approach;
   - Flight heritage
   - New technologies and technology development verification of TRL 5 by SCR/SRR and a development path towards TRL 6 by PDR.
5. Development Flow-
   - Development flowchart; test and verification flow, both at subsystem and system level
   - Make/buy info
6. Schedule
   - 1 chart only- major milestones, description of critical path
7. Risks
   - Identification of risks (constant with our risk management database) and risk mitigations

Documents Due by SRR/SCR

The following is a preliminary list of the ***draft*** documents that need to be in place by the SRR/SCR and available for the review team:

- Level 1 Requirements Document
- Mission Requirements Document
- Project Plan
- IIR Plan
- Tech Resource Spreadsheets (mass, power, Delta-V, data capture)
- Alignment Budget
- Operations Concept Document
- CM Procedure
- Education Outreach Plan
- Detailed WBS/ Scope of Work
- Letters of Agreement
- Systems Verification and Environments Definition Document
- System Engineering Management Plan
- Parts Radiation Control Plan
- MAR
- Spacecraft PAIP
- Risk Management Plan
- SDO Trade Studies report
- EMI Reqs
- Radiation Environment White Paper
- SDN Spec

Appendix D. SDO PDR Goals, Objectives, & Criteria

Note: Objectives and success criteria based on guidelines compiled from the NASA Systems Engineering Handbook, Space Science Enterprise Management Handbook, and Code 300 Review Guidelines.

PRELIMINARY DESIGN REVIEW (PDR) – The Preliminary Design Review (PDR) demonstrates that the "right system" has been chosen by demonstrating that:

1) A preliminary design exists that is compliant with the requirements and operations concept;
2) The cost, schedule and risk are consistent with project resources and constraints;
3) Justifies that the maturity of the design effort is appropriate to support proceeding with detailed design activities.

The PDR is not a single review but a number of reviews that includes the system PDR and PDRs conducted on specific lower level subsystem elements. At the Mission Level PDR, the project summarizes the results of these lower level reviews and discloses a preliminary system design to an independent review along with the results of the lower level reviews.

1 – Purpose – The PDR demonstrates that the preliminary design meets requirements for the system of interest with acceptable risk. It shows that the correct design option has been selected, interfaces identified, and verification methods have been satisfactorily described. It also establishes the basis for proceeding with detailed design.

2 – Timing – The PDR is held after the design team has completed a full functional implementation. The PDR is the first major review of the design and is normally held prior to the preparation of formal design drawings. A PDR is held when the design is advanced sufficiently to begin some bread board testing and /or the fabrication of design models. The design is held before the commitment to expend large scale resources involved in detailed design and development of engineering test units.

3 – Objectives - The objectives of the PDR are to:

1) Ensure that all system requirements have been allocated, the requirements are complete, and the flowdown is adequate to define the system, define the system's interfaces and verify system performance. Requirements traceability and flowdown from higher-level reqs should be clearly demonstrated.

2) Show that the proposed design is expected to meet the functional and performance requirements consistent with the operations concept at the system or subsystem element level.

3) Show sufficient maturity in the proposed design approach to proceed to final design. This is accomplished through the presentation of a specific design implementation coupled with an operations approach (including testing and verification), both consistent with each other and the system or subsystem requirements. Major drivers and issues are clearly identified

4) Show that the design is verifiable and that the risks have been identified, characterized, and mitigated where appropriate.

Detailed designs are not expected at this time, but system engineering, resource allocations and design analyses are required to demonstrate compliance with requirements. A presentation of the design and interfaces by means of block diagrams, signal flow diagrams, schematics, logic diagrams, error budgets, link margins, first interface circuits, packaging plans, configuration and layout sketches, analyses, modeling and any early results are required. Estimates of weight, power, volume and the basis for the estimates of these parameters are required. Supporting data and analyses for mechanical, power, thermal, and electronic design: load, stress, margins, reliability assessments, should be shown. Software requirements, design, structure, logic flow diagrams, Central Processing Unit (CPU) loading, design language and development systems need to be specified. Parts selection, de-rating criteria, and radiation hardness, is an important part of the PDR. The identification of single point failure modes needs to be assessed as well as critical design areas which may be life limiting

4 – Criteria for Successful Completion

The following items compose a checklist to aid in determining readiness of PDR product preparation:

1) Can the proposed preliminary design be expected to meet all the requirements within the planned cost and schedule?
2) Have all external interfaces been identified?
3) Have all the system requirements been allocated down to the subsystem element level?
4) Are all subsystem requirements complete, documented and ready for formal approval and release?
5) Has an acceptable operations concept been developed?
6) Does the proposed design satisfy requirements critical to human safety and mission success?
7) Is the proposed design producible? Have other groups and organizations involved in the production, verification and operation of this design reviewed the implementation approach and agreed that it can be implemented within the cost and schedule constraints? Have long lead items been considered?
8) Do the system requirements and preliminary design detail/documentation provide sufficient guidance and constraints to allow the designers to move ahead into the detailed design phase and complete the system design?
9) Has a reliability analysis been conducted and the results actively used to improve or verify the mission design and meet mission performance and life requirements?
10) Are sufficient project reserves and schedule slack available to complete the effort? Is there a clear organization chart with designated responsibilities, as well as a clear WBS to demonstrate the planned work and appropriately applied manpower and project resources?
11) Are there adequate risk management processes in place to identify areas of concern and formulate plans to address these areas?

5 – Results of Review - As a result of successful completion of the PDR, the "design-to" baseline is approved. It also authorizes the project to proceed to final design. The completion of the PDR and the closure of any actions generated by the review become the basis for the start of the detailed drafting and design effort and the purchase of parts, materials and equipment needed.

No project is expected to have a perfect score on the above criteria. The review chairman (in consultation with the review team) will assess the degree to which the above criteria have been met, the criticality of the areas where there are shortfalls, how straightforward and likely to succeed are the project’s recovery plans, and other relevant factors in making a judgment as to whether the PDR has been successfully completed. Successful completion may be contingent on the responses to some or all of the RFAs generated at the review. In some cases a delta PDR may be required for the project to successfully pass this milestone.

Documents Due by SDO PDR

The follow documents should be baselined under CM by SDO Mission PDR:

SDO Mission Level Documents (apply across all subsystems):

- Configuration Management Plan
- Observatory Mass Budget
- Observatory Power Budget
- Observatory Data Capture Budget
- Observatory Alignment Budget
- Mission Assurance Requirements (MAR)
- Observatory and Component TV and TB Requirements
- Mission Requirements Document (MRD)
- Project Plan
- Mission Operations Concept Document
- Environmental Verification Requirements
- Electrical Systems Specification
- Power Distribution Diagram
- Structural Analysis and Test Requirements
- Contamination Control Plan

Project Documents:

- Integrated Independent Review (IIR) Plan
- Subsystem Development Plans (one for each subsystem)

Mission Assurance:

- Risk Management Plan
- System Safety Program Plan

Systems Team:

- Systems Engineering Management Plan (SEMP)
- SDO Integration and Test (I&T) Plan
- SDO Time Management and Distribution Document

ACS:

- ACS Subsystem Specification
- ACS Components SOWs/Specifications (IRU, Star Trackers, Wheels)
- ACE SOW/Specification
- Goddard Dynamic Simulator Requirements/ICD
- ACE cPCI Target Requirements Document

Thermal:

- Thermal Subsystem Specification

Power:

- Power Subsystem Specification
- Low Voltage Power Switching Card (LPSC) Requirements/ICD
- Power Converter Card (PCC) Requirements/ICD
- Power Systems Electronics (PSE) Specification
- PSE cPCI Target Requirements Document

Flight Dynamics:

- Flight Dynamics Requirements Document

Ka-Band RF:

- Ka- Band Subsystem Specification
- HGA SOW/Specification
- Ka- Band Transmitter Specification

Propulsion:

- Propulsion Subsystem Requirements Document
- Propulsion Subsystem Design Specification
- Propulsion Components Specifications/SOWs (He Tank, Fuel Tank, Main Engine)

Ground System:

- Detailed Mission Requirements (DMR) Document

S-Band RF:

- S-band Subsystem Specification
- S-band Subsystem Specification/SOW

Mechanical:

- Mechanical Subsystem Specification
- Deployment System Requirements

High Gain Antenna System (HGAS):

- HGAS Specification
- Gimbal Actuator SOW/Specification
- Gimbal Slip/Roll Ring SOW/Specification
- Gimbal Rotary Joint SOW/Specification
- HGAS Pointing Requirements Spreadsheet

C&DH:

- C&DH Subsystem Specification
- High Speed Bus (HSB) ICD
- cPCI Backplane Requirements Document

Flight Software:

- 1553 Bus ICD

Subsystem Data Node (SDN):

- SDN Core Requirements Specification

cPCI Targets:

- cPCI to Local Bus ICD
- cPCI to LPSC (Low Voltage Power Switching Card) and PSE cards ICD

Electrical GSE (EGSE):

- S/C Simulator for Instruments Requirements Document

Instruments:

- HMI Contract Performance Requirements/SOW
- HMI to S/C ICD
- HMI PAIP
- AIA Contract Performance Requirements/SOW
- AIA to S/C ICD
- AIA PAIP
- EVE Contract Performance Requirements/SOW
- EVE to S/C ICD
- EVE PAIP