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Maunakea Spectroscopic Explorer: A Guide to Manage an International Design Team

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ABSTRACT

Maunakea Spectroscopic Explorer (MSE) is an international project supported by a culturally and geographically diverse design team that is centrally managed by the Project Office. Given the finite PO resources, it is imperative to provide a comprehensive plan to set the design team's performance standard. MSE has created an integrated plan with configuration management and review process over MSE's development, from conceptual design to science operations. The plan is a document-based system driven by mandatory reviews through the MSE development phases. This paper defines the objectives and expected outcomes of each mandatory review, and lists the titles, contents, developmental maturity and Configuration Management (CM) status of every document in required review data package. This paper also describes the Change Control protocol, within the CM framework, managed by formal Change Control Boards using a collection of configurable documents provided by the design team and the PO.

Keywords: configuration management, change control, configuration index, project review, work breakdown structure, risk register, cost book, design phase

1. INTRODUCTION

Maunakea Spectroscopic Explorer[1] (MSE) is the first of the future generation of massively multiplexed spectroscopic facilities. MSE is designed to enable transformative science, being completely dedicated to large-scale multi-object spectroscopic surveys, each studying thousands to millions of astrophysical objects. MSE uses an 11.25 m aperture telescope to feed 4,332 fibers over a wide 1.52 square degree field of view. It will have the capabilities to observe at a range of spectral resolutions, from R~3,000 to R~40,000, with all spectral resolutions available at all times and across the entire field. MSE's design development is supported by a culturally and geographically diverse design team that is centrally coordinated and managed by the Project Office (PO).

In this paper, we present an integrated Configuration Management and Review Plan[2] (CMRP) through the project's lifecycle, from conceptual design phase to transition to science operations. The CMRP states the mandatory reviews through MSE's developmental phases and specifies a configuration management process to control the project baseline, in terms of cost, schedule and scope†. The CMRP also set the expected development activities and outcomes of all reviews according the project developmental phases: conceptual design phase; preliminary design phase; detailed design phase; manufacturing and shipping phase; assembly, integration and verification phase; and science validation phase, Figure 1. The details of the planned project reviews are described in Appendix A. The project ends after the last phase and transitions into science operations.

In addition, the CMRP defines the associated review data packages of the required documents for each mandatory review. It lists the titles, contents, expected developmental maturity with respect to their configuration management

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† Scope includes established project-wide practices such as standards, processes and procedures, and in addition to MSE's features, functionalities and system performance.

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status of every project document required in the review data packages. Within the CM framework, the CMRP states the MSE's documentation hierarchy and specifies the configurable documents that are relevant to MSE's baseline. The CMRP also imposes a formal Change Control Board (CCB) and Change Control protocol for a subset of the configurable documents that are under Change Control. A configurable document is destined for Change Control if it affects the project baseline, regardless of its ownership, originated from the design team or Project Office.

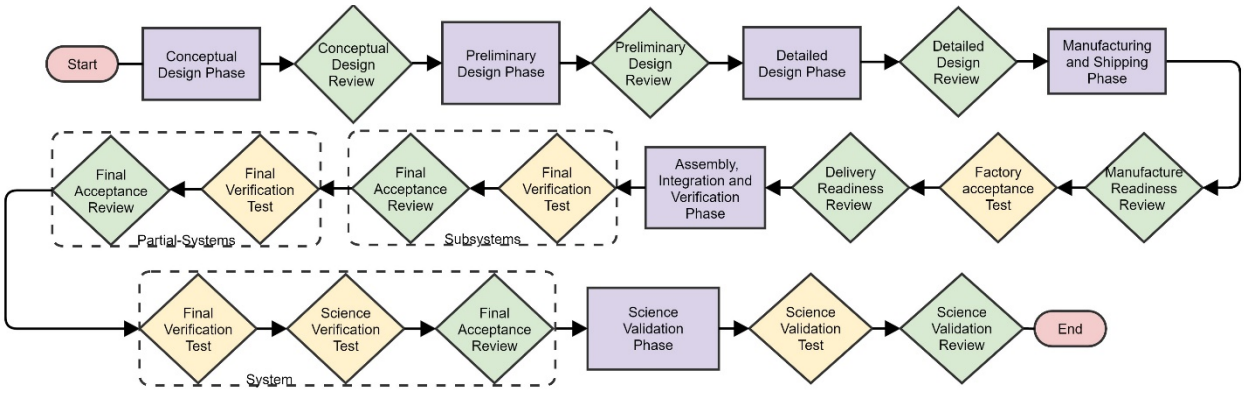

Figure 1 Block diagram of the project phases, reviews and tests sequence - all reviews are common for the System and subsystems, except for the system-level science validation review.

In addition, the Change Control protocol defines the Change Control actions and the composition of CCB with members from the design team, PO and/or the MSE governing board, and the decision authority. Likewise, depending on the development phase, the reviews plan defines the composition of the review panels and the decision authority, with internal and external members. However, the CMPR does not cover the management of computer aided design files in their native formats, the systems engineering aspect of requirements management, and the Project's issue tracking process. They are managed using specialized software adopted by the PO such as SOLIDWORKS PDM™, DOORS™ and Redmine™, etc. Their managing procedures are software specific.

2. CONFIGURATION MANAGEMENT AND CHANGE CONTROL

Configuration Management is the practice of establishing and managing MSE's Observatory configuration while it evolves through development phases following its design requirements. The CM process first defines a collection of distinct configurable items that fully characterizes the Observatory and then monitors continuously changes of the configurable items as dictated by the Change Control process.

2.1 Configurable Items

Configurable items are the building blocks of the Observatory during the design and development phases. When used as an ensemble, the configurable items uniquely describe the Observatory in its design architecture along with the science operations envisaged, and the associated processes and procedures adopted for MSE's design and development phases. Examples of configurable items are hardware and software designs, their associated design requirements documents, interface control documents, design reports, review processes, approval procedures, and specific programmatic elements such as risk register, cost and schedule to realize a positive outcome, etc. For MSE, the configurable items are represented by a set of selected documents. Therefore, the Observatory configuration is defined by its configurable documents designated by the PO.

All the configurable documents are available for release and at the end of the conceptual design phase before they can be "configuration managed". Once released, not all configurable documents are under the formal Change Control process. Generally, only a subset of configurable documents are designated as Change Control items. However, all configurable documents are Version-Indexed by MSE's central document repository that curates configurable documents by assigning unique version identifier to every revision of the same configurable document with the same title.

2.2 Change Control and Change Requests

Change Control is the ongoing process of decision-making to accept or reject proposed changes against the baseline, i.e., cost, schedule and scope. Change Control is a process to raise formal Change Request that describes the changes, assess and record their impacts on the baseline, and the organizational structure to approve or reject the proposed changes. Details of the Change Control process and delineation of the Change Control Board responsibilities are illustrated in Figure 2.

In general, Level 0 and Level 1 Change Requests are raised by the Project Office affecting Science and System level Change Control documents, and Level 2 Change Requests are raised either by the subsystem design teams or the Project Office affecting the subsystem level Change Control documents.

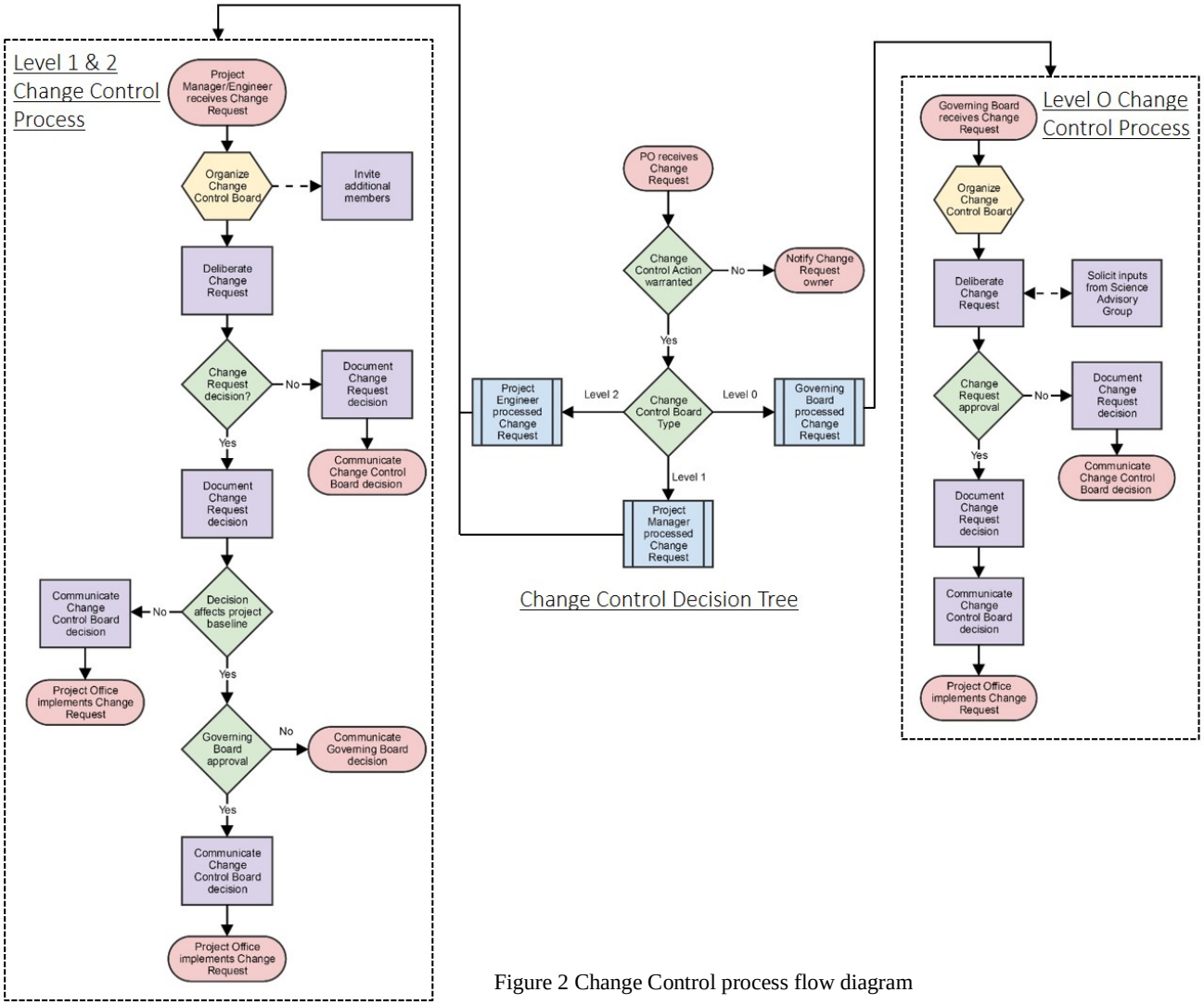

Figure 2 Change Control process flow diagram

Level 0 Change Requests: They affect the configurable documents listed in *Table 1*,and are directed to MSE's Governing Board CCB. The Governing Board appoints its chair, and the CCB works with consultation from the Science Advisory Group (SAG).

Level 1 Change Requests: They affect the configurable documents listed in *Table 2*, and are directed to the PO CCB with the Project Manager (chair), Project Scientist and Project Engineer as members. At the discretion of the chair, additional members may be invited to join the CCB.

Level 2 Change Requests: They affect the configurable documents listed in *Table 3*, and are directed to the Project Engineer who chairs the subsystem CCB with selected members from the Project Office and designated members from the design teams whose subsystems are directly affected by the Change Request.

In summary, Configuration Management maintains the status and integrity of MSE's configuration through its development phases by monitoring changes in project documents that are identified configurable and enforcing the Change Control procedure on those placed under Change Control.

3. CONFIGURABLE DOCUMENT ATTRIBUTES AND THEIR PROJECT LIFE CYCLE

The configurable document's attributes are document category, title, type and configured status, i.e., Version Indexed vs. Change Control. The configurable document sets and their status attributes according to the PO's planned technical and science reviews are tabulated in Table 1, Table 2 and Table 3. The contents of each documents are described in the next section.

Where applicable, the tables also specify when specific configurable documents transition from Version Indexed into Change Control at the end of a development phase review. The PO is responsible for maintaining the Level 0 and 1 configurable documents, and the subsystem design teams are responsible for maintaining the Level 2 configurable documents.

Table 1 Level 0 document sets and configured status according to the project phases

			Project Review[a]						
Document Category[b]	Document Title[c]	Document Type[d]	CoDR	PDR	DDR	MRR	DRR	FAR	SCR
	Configuration Index Document		CC	CC	CC	CC	CC	CC	CC
Requirement	Concept of Operations	REQ	-	CC	CC	CC	CC	CC	CC
	Science Requirements Document	REQ	CC	CC	CC	CC	CC	CC	CC
	Change Requests Record	SYS	-	CC	CC	CC	CC	CC	CC
Supplemental	Detailed Science Case	RPT	VI	VI	VI	VI	VI	VI	VI
	Science Reference Observations	RPT	VI	VI	VI	VI	VI	VI	VI
Validation	Science Validation Plan and Report	PLA	-	-	-	VI	CC	CC	CC

[a]Status at the end of each review, the project reviews are described in Section 4, and the status is described in Section 9.7

[b]Document categories are described in Section 3.1.

[c]Document titles and contents are described in Section 6.

VI = Version Indexed, i.e. current version is deposited in the document repository and identified by its locator.

CC = Change Control, i.e. document is under change control.

[d]Document type is described in Appendix B.

3.1 Contents of Configurable Documents

The configurable documents and their contents are list alphabetically:

Annual Operations and Staffing Cost Document: This document is a companion document to the OCD. Based on the top-down OCD's organizational structure, it outlines the actual scientific and technical staff size and composition, the managerial structure to enable efficient operations, staffing and operations costs, and annual budgets for community engagement, future observatory upgrade and site restoration after decommission, etc.

Assembly Drawings: The assembly drawings show the physical configuration of the subsystem. The assembly drawings contain multiple views showing the subsystem, with its assemblies and lower level products, at its different orientations within its ranges of motion, and with sectional views where the subsystem's assemblies otherwise would be obscured.

Assembly and Integration (A&I) Plan: The system A&I plan is a detailed procedure to assemble the Observatory by progressive integration of its subsystems. Moreover, the A&I plan includes the deconstruction of the existing CFHT facility in addition to new construction. The subsystem A&I plan describes its reassembly and integration process at the post-delivery site where system A&I activities are performed. The PO is responsible for coordinating the overall system A&I plan of the Observatory by incorporating the subsystems' A&I plans, and delivery sequence of the subsystems. The system plan coordinates all A&I activities to provide oversight on site access, site storage, staging area, crane access and usage of utilities, and to ensure efficiency and maintain overall health and safety.

Change Requests Record (CRR): The CRR curates the Level 0, 1 & 2 CRs, the corresponding decisions of the CCBs, and the outcomes of the CRs with respect to the affecting change-controlled documents.

Compliance Matrix: The system compliance matrix lists each requirement in the 0 SRD and Level 1 requirement documents, and the subsystem compliance matrices list each requirement in the Level 2 DRD and ICD. The compliance matrix states each requirement's compliance status, i.e. compliant, non-compliant or in-progress if further work is required, according to the project development phase reviews. It includes supplemental notes and hyperlink references to the documents listed in the CID showing the most recent evidence of compliance. At the final verification event, each requirement's compliance would link to its individual entry in the associated verification reports.

Concept of Operations (ConOps): The ConOps interprets the MES partnership's aspirations and expectations, and synthetize them into intended science objectives and principles for implementation into MSE's design architecture and operations concept at the system-level.

Configuration Index Document (CID): As its name indicates, this is the principal Configuration Management document. The CID is an index of all configurable documents representing Level 0, 1 & 2 products. Essentially, each the CID is a "snapshot" of all configurable items and their unique Version Indexes in the document repository.

Configuration Management and Reviews Plan: The plan is described in this document.

Cost Sheet: The subsystem Cost Sheet is an estimate of cost and schedule to deliver the work component described in the WBS dictionary. The subsystem cost and schedule are appraised from its lower level products.

Design Description Document (DDD): The DDD is a summary document prepared specifically for each technical review. As a minimum, the DDD should contain:

- Executive summary of the subsystem design highlighting the driving design requirements, statuses of applicable new and/or critical enabling technologies required, and long-lead purchases.
- If applicable, a summary of design evolution since last review with description of trade studies and rationale used to arrive at the latest design solution.
- An overview of the subsystem in terms of the functional architecture realized by its lower level functional products
- Using a top-down systematic approach by dividing the subsystem into lower level functional products, e.g. block-diagram representing the subsystem by its functional structure with lower level products.
- Lower level functional products description and specifications to demonstrate the selected concept in terms of optical, electrical, mechanical, thermal, and software design, etc. leading to an optimum result.
- Demonstration understanding of the design requirements in terms of the expected operating modes and its system behavior with respect to its functional products.
- Schematics, cabling/wiring and pipeline diagrams of all electrical, electronic, cooling, cryogenic and other services with level of details appropriate to the development phase expectations.

Table 2 Level 1 document sets and configured status according to the project phases

			Project Review[a]					
Document Category[b]	Document Title[c]	Document Type[d]	CoDR	PDR	DDR	MRR/DRR	FAR	SCR
	Configuration Index Document	SYS	CC	CC	CC	CC	CC	CC
Requirement	Observatory Architecture Document	REQ	CC	CC	CC	CC	CC	CC
	Operations Concept Document	REQ	CC	CC	CC	CC	CC	CC
	Observatory Requirements Document	REQ	CC	CC	CC	CC	CC	CC
Design	General Assembly Drawings	DWD	-	VI	VI	CC	CC	CC
	Engineering Standard List	STD	-	VI	CC	CC	CC	CC
	Telescope Optical Design	RPT	VI	CC	CC	CC	CC	CC
	Sensitivity Budget (partitioned in five system budgets)	SYS	VI	VI	VI	VI	VI	VI
	Observing Efficient Budget	SYS	VI	VI	VI	VI	VI	VI
Supplemental	Interface Definitions Document	SYS	VI	VI	VI	VI	VI	VI
	Sky Subtraction Requirements Analysis	RPT	VI	VI	VI	VI	VI	VI
	Spectrophotometry Requirements Analysis	RPT	VI	VI	VI	VI	VI	VI
	Analysis Reports	RPT	VI	VI	VI	VI	VI	VI
	Technical Memorandums and Budgets	RPT	VI	VI	VI	VI	VI	VI
Safety	Hazard Analysis and Risk Assessment Report	RPT	-	VI	VI	CC	CC	CC
	Health and Safety Plan	PLA	-	VI	VI	CC	CC	CC
Reliability	Failure Modes and Effects Analysis Report	RPT	-	VI	VI	VI	VI	VI
	Reliability Report	RPT	-	VI	VI	VI	VI	VI
Operations	Design Reference Survey	PLA	-	VI	VI	VI	VI	VI
	Science Calibration Plan	PLA	-	VI	VI	CC	CC	CC
	Maintenance Plan	PLA	-	-	VI	CC	CC	CC
	Spares and Consumables List	SPE	-	-	VI	CC	CC	CC
	Annual Operations and Staffing Cost Document	MGT	-	VI	VI	CC	CC	CC
Verification	Assembly and Integration Plan	PLA	-	VI	VI	CC	CC	CC
	System Verification Plan and Report	PLA	-	-	VI	CC	CC	CC
	Science Verification Plan and Report	PLA	-	-	-	VI	CC	CC
	Compliance Matrix	SYS	VI	VI	VI	VI	VI	VI
Quality Control	Product Assurance Plan	PLA	-	VI	CC	CC	CC	CC
	Product Assurance Report	RPT	-	-	VI	CC	CC	CC
	Configuration Management and Reviews Plan	PLA	VI	CC	CC	CC	CC	CC
	Change Requests Record	SYS	-	CC	CC	CC	CC	CC
	Waivers	SYS	-	-	VI	CC	CC	CC
Programmatic	Work Breakdown Structure Dictionary	MGT	VI	CC	CC	CC	CC	CC
	Management Plan	MGT	VI	CC	CC	CC	CC	CC
	Project Cost Book	MGT	VI	CC	CC	CC	CC	CC
	Project Plan and Integrated Schedule	PLA, SCH	VI	CC	CC	CC	CC	CC
	Project Risk Register	MGT	VI	CC	CC	CC	CC	CC

[a]Status at the end of each review, the project reviews are described in Section 4, and the status is described in Section 9.7

[b]Document categories are described in Section 3.1.

[c]Document titles and contents are described in Section 7.

VI = Version Indexed, i.e. current version is deposited in the document repository and identified by its locator.

CC = Change Control, i.e. document is under change control.

[d]Document type is described in Appendix B.

Table 3 Level 2 document sets and configured status according to the project phases

Document Category[b]	Document Title[c]	Document Type[d]	Project Review[a]					
			CoDR	PDR	DDR	MRR	DRR	FAR
	Configuration Index Document	SYS	CC	CC	CC	CC	CC	CC
Requirement	Design Requirements Document	REQ	VI	CC	CC	CC	CC	CC
	Interface Control Document Set	ICD	VI	CC	CC	CC	CC	CC
Design	Design Description Document	RPT	VI	VI	VI	VI	VI	VI
	Software Architectural Document	RPT	-	VI	CC	CC	CC	CC
	Assembly Drawings	DWG	-	VI	CC	CC	CC	CC
	Fabrication Data Set	DWG, PRO, SPE, etc.	-	-	VI	CC	CC	CC
Supplemental	Analysis Reports	RPT	VI	VI	VI	VI	VI	VI
	Technical Memorandums	RPT	VI	VI	VI	VI	VI	VI
	Associated models and simulation files	MOD	VI	VI	VI	VI	VI	VI
Safety	Hazard Analysis and Risk Assessment Report	RPT	-	VI	VI	CC	CC	CC
	Health and Safety Plan	PLA	-	VI	VI	CC	CC	CC
Reliability	Failure Modes and Effects Analysis Report	RPT	-	VI	VI	CC	CC	CC
	Reliability Report	RPT	-	VI	VI	CC	CC	CC
Operations	Operations Concept and Operator's Manual	PLA	-	VI	VI	CC	CC	CC
	Maintenance Plan	PLA	-	-	VI	CC	CC	CC
	Spares and Consumables List	SPE	-	-	VI	CC	CC	CC
Verification	Assembly and Integration Plan	PLA	-	-	VI	CC	CC	CC
	Verification Plan and Report	PLA	-	-	VI	CC	CC	CC
	Compliance Matrix	SYS	VI	VI	VI	VI	VI	VI
Quality Control	Manufacturing and Shipping Plan	PLA	-	VI	VI	CC	CC	C C
	Product Assurance Plan	PLA	-	VI	VI	CC	CC	CC
	Product Assurance Report	RPT	-	-	-	VI	CC	CC
	Change Requests Record	SYS	-	CC	CC	CC	CC	CC
	Waivers	SYS	-	-	-	VI	CC	CC
Programmatic	Management Plan	PLA	-	VI	VI	VI	VI	VI
	Cost Sheet	MGT	VI	CC	CC	CC	CC	CC
	Schedule	SCH	VI	CC	CC	CC	CC	CC
	Risk Register	MGT	VI	CC	CC	CC	CC	CC

[a]Status at the end of each review, the project reviews are described in Section 4, and the status is described in Section 9.7

[b]Document categories are described in Section 3.1.

[c]Document titles and contents are described in Section 8.

VI = Version Indexed, i.e. current version is deposited in the document repository and identified by its locator.

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[d]Document type is described in Appendix B.

- Description of the external interfaces with other subsystems, and critical internal interfaces among the assemblies with level of details appropriate to the development phase expectations.
- Description of the state of development for new and/or critical enabling technologies
- Summary of compliance with design requirements and engineering standards, including status against technical budgets such as reliability, maintenance, mass, power, thermal etc.
- Summary of hazard, and health and safety assessments according the development phase expectations.
- Summary of major programmatic risk assessments according the development phase expectations.

Design Reference Survey (DRS): The DRS is a supplemental to the SRO for crosschecking the capability of the Observatory design. It consolidates selected SROs into an executable survey plan by taking into account of external and technical constraints based on the system and subsystem designs.

Design Requirements Document (DRD): Every subsystem is responsible for its DRD. A subsystem DRD defines the performance and functional design requirements that are traceable to the Level 1 ORD.

Detailed Science Case (DSC): The DSC is the foundational document for MSE's expected science capabilities. It is the science narrative listing the principal science goals and describes its impacts on a broad range of science topics.

Fabrication Data Set: The subsystem fabrication data set is full set of as-built engineering data including the bill of materials, fabrication drawings, part drawings, component specifications, assembles and installation procedures. It enables the Observatory staff to maintain, repair and replace parts of the subsystem throughout the Observatory's lifetime. In most cases, the data set progresses from a set of as-designed fabrication drawings presented at the Detailed Design Review and evolves into the as-built drawings after the Final Acceptance Review.

Failure Modes and Effects Analysis (FMEA) Report: The FMEA is a systematic examination of interactions among the subsystems in order to identify how individual and combined subsystem failures may affect system operations. Effects from the FMEA that compromise safety will be incorporated into the system HARA, where appropriate.

General Assembly Drawings (GAs): The GAs show the Observatory configuration represented by the Level 2 subsystems. They drawings contain multiple views showing the integrated system with subsystems at their different orientations within their ranges of motion, and with sectional views where subsystems otherwise would be obscured.

Hazard Analysis and Risk Assessment (HARA) Report: The HARA reports identify potential hazards and evaluate risks through the life of the Project at the system and subsystem level, and recommends mitigation strategies.

Health and Safety (H&S) Plan: The H&S plan defines the procedures, equipment and personnel training required at the Observatory level to ensure health and safety of the staff, equipment, public and environment through the life of the Project. Where appropriate, mitigation strategies pertaining to H&S issues from the HARA report are incorporated.

Interface Control Document (ICD) Set: Every subsystem has a set of ICDs that describes its interface requirements with other subsystems. The PO assigns the interface responsibilities that a subsystem is required to characterize and define. The PO manages the interfaces with inputs from the subsystem design teams, and the interface requirements are traceable to the ORD.

Maintenance Plan: The system maintenance plan consolidates the subsystems' maintenance plans into logical and cohesive sequences in order to optimize workflow and operations efficiency, and verifies from bottom-up if MSE's maintenance budget are met and the combined nighttime maintenance time is consistent with the observing efficiency budget. The subsystem-level maintenance plans summarize the anticipated maintenance activities required to support subsystem operations. Each plan describe the scheduled preventative maintenance tasks including their procedures, sequencing, frequencies, durations, resources (personnel, equipment, and utilities) required to complete each maintenance task, and specifically instructions steps related to health and safety, etc.

Management Plan: The management plan is a supplementary document to the Cost Sheets prepared by the PO and design teams, which contain the cost and schedule estimates, and outlines organizationally the workflow by which either the PO or the design teams plan to complete and deliver the work represented in the Cost Sheets. In addition to describing how the work is accomplished, the plan states the assumptions and methodologies used to derive the cost and schedule estimates, such as cost models and empirical data, etc. In addition, if any new and/or critical enabling technologies are required then their development and demonstration strategies are included in the management plan. Any long-lead items and purchases are also identified in the subsystem plan.

Manufacturing and Shipping (M&S) Plan: The M&S plan is a detailed step-by-step procedure outlining the fabrication and assembly of a subsystem from its assembled components, leading to its Factory Acceptance Test, and then its disassembly, packing and shipping to the designated A&I site, including considerations for overall health and safety. The plan also includes shipping considerations such as specialized containers and handling, and metrology steps consistent with the Product Assurance plan during the fabrication and assembly processes.

Since the subsystem design team is responsible for its fabrication and assembly equipment, utilities, and overall health and safety during the Manufacturing and Shipping Phase at their site, the M&S plan highlights special concerns and their resolutions in these areas.

Observatory Architecture Document (OAD): The OAD defines the observatory architecture expressed in its physical and functional design in response to the SRD, and specifies the corresponding system performance budgets in order to fulfill the SRD's sensitivity requirements. MSE's architecture is expressed in a product breakdown structure. The OAD contains high-level design decisions that are traceable to the ConOps, and defines a performance budget framework to account for system sensitivity allocated to the subsystems.

Observing Efficiency Budget: This budget delineates subsystems' configuration time, maintenance and reliability budgets.

Operations Concept Document (OCD): The OCD defines an observatory organization and its workflow in response to the ConOps, SRD and OAD. The workflow describes the scientific and operational processes and procedures to enable delivery of the science products that meet the scientific requirements in the SRD. It allocates maintenance and reliability budgets to subsystems in accordance to the SRD observing efficiency requirement.

Operations Concept and Operator's Manual: The operations concept and operator's manual is a companion document to the DDD. It identifies all the operating modes of the subsystem in context of observation activities including start up, shut down, configuration, calibrations and safety events, etc. It also describes for the observatory operator the expected input and output behavior to control and communication during different observing and operating modes.

Observatory Requirements Document (ORD): The ORD processes the OAD and OCD and constitutes a set of cohesive Level 1 requirements. It serves as the requirement repository where the intrinsically implied OAD and OCD requirements are collected in the same way the OAD processes the ConOps and SRD requirements, and is the "parent" where the Level 2 subsystem requirements trace their origin.

Product Assurance Plan: The plan is a process-focused document that identifies the processes and their enforcement to ensure the quality of the delivered Observatory is as intended. In general, the system PA plan includes the PO activities for monitoring and establishing traceability of compliance for the these elements: Configuration Management and Change Control process; review processes; subsystem acceptance reviews processes; system and subsystem A&I processes; system and science verification processes; purchased item inspections; contractor certificates of compliance; and waiver process, etc.. In general, a subsystem PA plan includes activities for monitoring and establish traceability for these elements: design standards; workmanship standards; purchased item inspections; in-process inspections; supplier acceptance tests; and subcontractor certificates of compliance, etc. In most cases, the certified in-house PA plan from a partner, contractor, and supplier/vendor are deemed satisfactory by the PO.

Product Assurance Report: The system PA report collects and documents the results from the PO's PA activities to verify compliance against the PA plan. The subsystem PA report collects and documents the results from the activities according to the PA plan to verify compliance.

Project Cost Book: The Cost Book consolidates the system and subsystem cost estimates based on the work component descriptions in WBS dictionary. The MSE Cost Book is a collection of Excel files with the cost (and schedule timeline) of each WBS work component estimated an individual Cost Sheet. The project cost is consolidated in a master file with links to the cost information from individual Cost Sheets, and the Excel's pivot table tool enables additional financial analysis with the Cost Book data.

Project Plan and Integrated Schedule: MSE's project plan is contained in a Microsoft Project file using the schedule information from the Cost Sheets of the each work component in the WBS. In addition to integrating the system and subsystem schedule estimates into logical sequences, the PO imposes programmatic constraints based on management considerations in developing of the project plan.

Project Risk Register (PRR): The PRR is used to manage risks. As risks are identified, they are logged in the risk register and mitigation actions are formulated in respond to the risks. The risk register documents, quantifies and manages the project risks based on the appraised level of risk exposure (RE). In addition to the system risks, subsystem risks with high REs from lower-level risk registers may be elevated to project-level and incorporated in the PRR.

Reliability Report: The system reliability report summarizes of the subsystems' reliability predictions and verifies the overall OCD's observing efficiency budget can be met "bottom-up" by the subsystems. The subsystem reliability reports summarize individual subsystem's reliability and verifies the top down OCD's observing efficiency budget allocation is met.

Risk Register: The risk register contains risks identified by the subsystem design team, including proposed risk mitigation actions. Subsystem risks with sufficient high REs may be elevated to the Project Risk Register.

Schedule: The Schedule is a supplemental document to the subsystem Cost Sheet timeline organized by the project development phases including task descriptions, their link-logic and durations, and resource allocations information. The Schedule is provide by the subsystem design teams.

Science Calibration Plan (SCP): The SCP is a companion document to the operations concept of the Science Calibration System that is a hardware-based subsystem with requisite methodologies, procedures, algorithms and control software, etc. to achieve the required accuracy in wavelength solutions specified in the ORD.

Science Reference Observations (SRO): The SRO describes a list of transformational observing programs that span the range of science topics described in the DSC enabled by MSE. The SRD requirements are framed by the science capabilities required to conduct the SROs.

Science Requirements Document (SRD): The SRD dictates the system requirements that MSE shall meet.

Science Validation Plan and Report: It assesses if the Observatory operates as intended according to the DRS document, and contains the test plan that converts the DRS survey plan into step-by-step observing programs in order to assess if the observations envisaged can be executed effectively. The findings from science validation becomes recommendations future development in during science operations in order to improve scientific productivity.

Science Verification Plan and Report: The science verification plan describes the Science Verification Test to ratify if the Observatory meets the science requirements stated in the SRD. Each SRD requirement has a stated verification method and procedure, and provision for capturing the verified result. If actual observation is the required verification method then its verification plan defines the steps necessary to perform the observation, reference observing conditions, data reduction and processing tools, and the pass/fail criteria, etc. The intent of the science verification plan is to provide a comprehensive guide for planning and execution of the Science Verification Test activities, and the findings are recorded in the same document to form the science verification report.

Software Architectural Document (SAD): The SAD establishes traceability of proposed software design to the parent requirements in the subsystem DRD. With the software performance definitions expressed in measurable terms, the SAD demonstrates that the software design systematically meets all requirements associated with command, control, monitor and data communication of the subsystem in its interaction with the Observatory.

Spares and Consumables List: The system spares and consumables list consolidates the subsystems' spares and consumables lists and identifies common parts for optimal inventory strategies in conjunction with the preventative maintenance requirements and reliability predictions. The subsystem-level spares and consumables lists tabulate the recommended items that MSE should stock for optical, mechanical and electrical assemblies, etc. Each component listed should identify the item name, supplier, part number, replacement costs when purchased at the Manufacturing and Shipping phase and post-M&S, shelf life, lead-time, and special handling, shipping and storage instructions.

Supplemental Documents: By definition, the supplemental documents provide background information to support the Level 1 requirement documents and system performance budgets. Generally, supplemental documents are analysis

reports and technical memorandums in support of the proposed design, such as performance modelling reports predicting system and subsystem performances.

System Level Performance Budgets: The sensitivity requirements delineates the five performance budgets of noise, throughput, injection efficiency, point spread function and image quality.

System Verification Plan and Report: The system verification plan describes the system-level Final Verification Test (FVT) to ratify if the Observatory meets the design requirements stated in the Level 1 requirement documents - OAD, OCD and ORD. In this document, each Level 1 requirement has a stated verification method and procedure, and provision for capturing the verification result. The intent of the system verification plan is to provide a comprehensive guide for planning and execution of the FVT activities, and the findings are recorded in the same document to form the system verification report.

Telescope Optical Design: This represents the overall optical design that delivers the science focal surface at prime focus, including the segmented primary mirror, wide field corrector and atmospheric dispersion corrector.

Verification Plan and Report: The subsystem verification plan utilizes the FVT to ratify if the subsystem meets its design requirements stated in the DRD and ICD. In the subsystem verification documents, each design requirement or criterion has a stated verification method and procedure, and provision for capturing the verification result. The intent of the verification plan is to provide a comprehensive guide for planning and execution of the FVT activities, and the findings are recorded in the same document to form the verification report.

Waivers: A system waiver is a written authorization from the Project Manager, with consultation with the Governing Board, to accept a functional or performance aspect of the System that is found to be deficient from the specified requirement, but considered acceptable for use “as-is” or “as approved” after the proposed remedial method. A subsystem waiver is a written authorization from the PO to accept a functional or performance aspect of a subsystem after its Factory Acceptance Test that is found to be deficient from the specified requirement, but considered acceptable for use “as-is” or “as approved” after the proposed remedial method.

Work Breakdown Structure (WBS) Dictionary: The WBS describes the organization of work required to deliver the Observatory in terms of the work components. It lists the major work components divided in the required work to deliver MSE’s according to its Production Breakdown Structure including the level-of-effort work required to support the Factory Acceptance Tests, system-level assembly and integration activities, Final Verification Test, Science Verification Test, and Final Acceptance Reviews, etc. Based on the organization of the WBS items, the WBS dictionary describes in detail the included work and the excluded work in each work component, including the expected deliverables, and assigns explicit interface responsibilities between components. The purpose of the WBS dictionary is to facilitate cost and schedule estimate activities at the system and subsystem levels.

4. REVIEW DEFINITIONS, EXPECTATIONS AND PROCESSES

As stated, the PO manages MSE development by phases at the system (Level 1) and subsystem (Level 2) levels. At the completion of each phase, technical reviews are conducted to assess if the progress is consistent with level of maturity expected. Generally, a formal Review Panel with internal and invited external subject-matter experts conducts the review. If the system or a subsystem fail to meet the expected maturity, the review panel recommends remedial actions and possibly a supplemental review, i.e., delta-review, before progressing.

This section describes the expected levels of technical maturity for the project development phases and their associated technical reviews listed in Figure 1. The design and development activities of the specialized software products in Program Execution Software Architecture and Observation Execution Software Architecture may follow different methodologies depending on the design teams and after consultation with the Project Office.

4.1 Conceptual Design Phase Definition, Expectations and Review Process

Based on the initial design requirements, the Conceptual Design is the phase of development where alternate system and subsystem designs are compared, and a preferred design is selected by trade studies, performance analyses and risk assessments.

The Conceptual Design Phase (CoDP) expectations are framed by its design phase activities:

- Develop system-level functional, operational and performance requirements, establish their traceability with the science requirements, and document their interpretations OR develop subsystem requirements based on the Project Office proposed strawman requirements
  - At the Conceptual Design level, it is acceptable to have placeholder requirements to identify the pertinent design parameters with TBC or TBD designations for confirmation in the next development phase.
- Identify and explore multiple design concepts, which meet requirements, through modeling, trade studies and analyses.
- Select and justify the optimal design concept by its functional architecture and technical specifications in such a detail that:
  - Performance is quantified with generalized performance budgets.
  - All critical technical areas are highlighted and analyzed to identify gaps in the enabling technologies required.
  - Development plan for enabling technologies and potential resolutions are presented.
  - Major external interfaces and critical internal interfaces are identified with their interface feasibilities evaluated.
  - At the Conceptual Design level, it is acceptable to have some amount of uncertainties in performance predictions, technical feasibility, and placeholders to identify pertinent interfaces with TBC or TBD designations for confirmation in the next development phase.
- Using the top-down fabrication and construction concepts, develop the cost and schedule estimates for the Preliminary Design Phase, and the broad cost and schedule estimates to completion at final acceptance.
  - However, the cost and schedule, and the associated impacts due to technical and programmatic risks are estimated with a modest degree of confidence using limited information.
- Identify major technical and programmatic risks and their proposed migrations.

At the conclusion of the CoDP activities, the design is captured by the Conceptual Design Review (CoDR) data package. The data package contains documents listed the CoDR CID set listed in Table 2 for the Level 1 system CoDR data package, and the CID set in Table 3 for the Level 2 subsystem CoDR data package. The expected technical maturity of the CoDR documents must be consistent with the CoDP activities.

Based on the CoDR data package, the Conceptual Design Review is conducted to:

- Evaluate the adequacy of the engineering progress and technical assessment in selecting the proposed design from the alternate concepts considered. Examine the selected design's compatibility with the requirements.
- Determine the feasibility of the physical and functional interfaces among other subsystems, and, if applicable, with other items of handling equipment, facilities, communication and control at the observatory level.
- Evaluate the risk assessments of the selected design in terms of critical technologies, and feasibility for procurement, fabrication, assembly, integration and assembly.

The CoDR concludes the CoDP. The CoDR may result in revision of the project baseline prior to the subsequent Preliminary Design Phase (PDP). Before entering the PDP, a supplemental “delta-CoDR” may be required to close out remaining issues of the CoDP, if recommended by the Review Panel.

At the end of the Conceptual Design Phase, it shall be evident that:

- The selected design is attainable in terms of architecture, functionality and performance.
- The development plan for enabling technologies is viable.
- The associated cost, schedule and risks are understood with a moderate degree of confidence.
- All Configurable Items’ configured statuses are updated and verified.

4.2 Preliminary Design Phase Definitions, Expectations and Review Process

Based on the conceptual design, the Preliminary Design is the phase of development where the system and subsystem designs are affirmed as viable engineering solution, and the proposed designs is validated by detailed performance analyses and risk assessments.

The Preliminary Design Phase expectations are framed by its design phase activities:

- Refine system-level requirements and supporting documents to demonstrate that they are consistent and complete with respect to the science requirements OR refine subsystem requirements by flow-down to lower assembly level products to demonstrate they are complete and consistent.
    - At the Preliminary Design level, it may be acceptable to have placeholder requirements to identify the pertinent design parameters with TBC or TBD designations for confirmation in the next development phase. However, these uncertainties must be explained and justified.
- Advance the conceptual design by finalizing major design choices to demonstrate it meets the requirements in terms of functional and technical specifications, and the established cost and schedule constraints.
- The selected designs are complete in such a detail that:
    - System performance is verified by analyses with budgets that are partitioned at the subsystem-level OR subsystem performance is verified by analysis using budgets that are partitioned at the lowest-level functional products.
    - All technically critical areas have viable solutions, and major risks retired.
    - The critical technologies are validated through continued modelling, analyses and/or prototype testing and evaluation.
    - All external interfaces and major internal interfaces are described with detailed requirements.
    - Draft assessments for safety and reliability are produced, and the preliminary plans for maintenance; manufacturing and shipping; assembly and integration; verification and product assurance are provided.
    - At the Preliminary Design level, it may be acceptable to have a small amount of uncertainties in performance predictions, technical feasibility, and limited number of placeholders to identify pertinent interfaces with TBC or TBD designations for confirmation in the next development phase. However, these uncertainties must be explained and justified.
- Using refined fabrication and construction concepts, top-down and bottom-up, refine the cost and schedule estimates for the Detailed Design Phase, and the broad cost and schedule estimates to completion at final acceptance.
    - However, the cost and schedule, and the associated impacts due to technical and programmatic risks are estimated with a high degree of confidence using all available information.
- Identify all technical and programmatic risks and their proposed migrations.
- Develop management plan and procurement plan with long-lead items identified.

At the conclusion of the PDP activities, the design is captured by the Preliminary Design Review (PDR) data package. The data package contains documents listed the PDR CID set listed in Table 2 for the Level 1 system PDR data package, and the CID set in Table 3 for the Level 2 subsystem PDR data package. The expected technical maturity of the PDR documents must be consistent with the PDP activities.

Based on the PDR data package, the Preliminary Design Review is conducted to:

- Evaluate the adequacy of the engineering progress and technical assessment in the selected design architecture based on the expected progress from the PDP activities.
- Examine the selected design's compatibility with the requirements.
- Assess the compatibility of the physical and functional interfaces among other subsystems, and, if applicable, with other items of handling equipment, facilities, communication and control at the observatory level.
- Evaluate the adequacy of the draft safety and reliability assessments, and the preliminary plans for operations; manufacturing and shipping; assembly and integration; verification; product assurance and management.

- Evaluate the risk register of the selected design to assess the adequacy of the proposed risk mitigation strategies and identify any missing risk items.

The PDR concludes the PDP. The PDR may result in revision of the project baseline prior to the subsequent Detailed Design Phase (DDP). Before entering the DDP, a supplemental "delta-PDR" may be required to close out remaining issues of the PDP, if recommended by the review panel.

At the end of the Preliminary Design Phase, it shall be evident that:

- The selected design is attainable in terms of architecture, functionality and performance, and in terms of cost, schedule and producibility.
- The enabling technologies are available and their risks retired.
- Long-lead items and purchases are identified with procurement plan.
- The associated cost, schedule and risks are understood with a high degree of confidence.
- All Configurable Items' configured statuses are updated and verified.

4.3 Detailed Design Phase Definitions, Expectations and Review Process

The Detailed Design is the phase of development where the system and subsystem designs are finalized and completed, and the design compliance is fully verified by analysis, inspection, and/or prototype test.

The Detailed Design Phase expectations are framed by its design phase activities:

- Finalize the detailed System and subsystem specifications, subsystem interfaces, and their associated supporting documentations.
  - At the Detailed Design level, it is not acceptable to have placeholder requirements with TBC or TBD designations.
- At the system-level, finalize the system architecture and subsystem interfaces, operations concept, system performance budgets and the associated documentation OR at the subsystem-level, finalize the detailed specifications and internal interfaces of the subsystem's assemblies and the associated documentation, with the objective of supporting the procurement and/or manufacturing plans of these assemblies.
- The selected designs are finalized in such a detail that:
  - System and subsystem designs meet their requirements as a result of analysis, simulation, inspection and/or test.
  - System and subsystem designs and the associated documentation are complete including requirements for the production, assembly and integration, and operational phases.
  - At the assembly level, present cost-effective manufacturing plans, including options for in-house production or contracting out; and plans for assembly and integration, and verification.
  - Operational requirements associated with maintenance staff, consumables and spare parts are developed and documented.
  - Safety and reliability assessments are complete.
  - Initial plans for operations concept such as maintenance activities and cost; assembly and integration; verification and product assurance are drafted.
- Update the risk register, management plan and, if applicable, procurement plan.

At the end of DDP, the system and subsystem designs are fully documented, and their performance validated according to the analysis, inspection, and/or prototype test.

At the conclusion of the DDP activities, the design is captured by the Detailed Design Review (DDR) data package. The data package contains documents listed the DDR CID set listed in Table 2 for the Level 1 system DDR data package, and the CID set in Table 3 for the Level 2 subsystem DDR data package. The expected technical maturity of the DDR documents must be consistent with the DDP activities. The expected technical maturity of the DDR documents must be consistent with the DDP activities.

Based on the DDR data package, the DDR is conducted to:

- Confirm the design satisfies the requirements specified.
- Confirm the compatibility of the physical and functional interfaces among other subsystems, and, if applicable, with other items of handling equipment, facilities, communication and control at the observatory level.
- Confirm the safety and reliability plans
- Assess the adequacy of the proposed plans to ensure operations efficiency, producibility, assembly and integration, and product assurance.
- Evaluate the risk assessments of the proposed plans and the adequacy of the risk mitigation strategies to ensure the as-designed System and subsystems satisfy the requirements.

The DDR concludes the DDP. The DDR may result in revision of the project baseline prior to the subsequent Manufacturing and Shipping Design Phase. Before entering the M&S Phase, a supplemental "delta-DDR" may be required to close out remaining issues of the DDP, if recommended by the Review Panel.

At the end of the Detailed Design Phase, it shall be evident that:

- The selected design is fully realized as supported by the technical, production and programmatic documents presented.
- The associated cost, schedule and risks are quantified and presented with high degree of confidence.
- All Configurable Items' configured statuses are updated and verified.

At the end of DDP, the system and subsystem designs are fully documented, and their requirements realized according to the activities stated.

4.4 Manufacturing and Shipping Phase Definition, Expectations and Review Process

The M&S Phase begins after the completion of the DDP Phase. Generally, the M&S Phase is divided into two stages separated by the Manufacturing Readiness Review (MRR), and ends with the Delivery Readiness Review (DRR). The M&S Phase's reviews focus primarily on the processes related to safety, production, product assurance and final performance in order to ensure the as-delivered System and subsystems are functionally and operationally safe, and match the as-designed System and subsystems represented from the Detailed Design Phase.

4.4.1 Subsystem Manufacturing and Shipping Phase

For a subsystem, the MRR occurs before its fabrication start and the DRR occurs after its Factory Acceptance Test in order to qualify it for shipment. It is critical that this phase is not started until the subsystem design team has completely demonstrated that the design satisfies all requirements, and where the design does not satisfy requirements, any deficiencies are understood, change requests approval and/or waivers are received from the PO. Starting production with specifications that are changing and dynamic significantly increases the budget and schedule risks.

For some smaller subsystems, it is feasible to combine the DDR and MRR if the former contains the necessary information in meeting the MRR expectations. The determination of whether the two reviews can be combined is the choice of the individual subsystem design team working in consultation with the PO.

For high-value and high-risk subsystems such as the primary segment assemblies, it is prudent to divide the mirror segment fabrication work into M&S sub-phases: pre-production and main production, in order to fully qualify the production processes and their vendors. The determination of whether sub-phases should be implemented is based on the recommendations from the PO working in consultation with individual subsystem design team.

Table 3 lists the subsystem documents and their configured statuses for the subsystem MRR. However, only selected documents within the category: Safety, Verification, Quality Control and Programmatic form the subsystem MRR data package, including:

- Health and Safety (H&S) Plan

- Manufacturing and Shipping Plan
- Verification Plan pertaining to Factory Acceptance Test
- Product Assurance Plan
- Change Requests Record
- Cost and schedule, if revised
- Risk Register

Based on the MRR data package, the MRR is conducted to:

- Assess the adequacy of the H&S, M&S, verification and PA plans
- Evaluate if the design team have adequately addressed the concerns and recommendations from the Detailed Design Review Panel, including the usage of Change Requests to address design and performance deficiencies.
- Assess if the revised programmatic and technical risks after further risk mitigation activities since the DDR are deemed complete to begin fabrication.

At the end of the Manufacturing Readiness Review, it shall be evident that:

- The selected subsystem is sanctioned for fabrication, including any remedial actions required.
- All design deficits are identified and acknowledged by the Project Office through applicable Change Requests.
- All Configurable Items' configured statuses are updated and verified.

Before proceed to fabrication, a supplemental "delta-MRR" may be required to close out remaining issues, if recommended by the Review Panel.

Table 3 lists the subsystem documents and their configured status for the subsystem DDR after the Factory Acceptance Test. However, only selected documents within the category Design, Operations, Verification and Quality Control form the subsystem DRR data package, including:

- Software Architectural Document
- Fabrication Data Set
- Operations Concept and Operator's Manual
- Manufacturing and Shipping Plan
- Verification Report pertaining to the Factory Acceptance Test
- Assembly and Integration Plan at the designated delivery site
- Verification Plan pertaining to Final Verification Test
- Product Assurance Report pertaining to manufacturing
- • Change Requests Record
- • Waivers

Based on the DRR data package, the Delivery Readiness Review is conducted to:

- Verify if the selected subsystem has passed its Factory Acceptance Test.
- Confirm the Fabrication data set and operations concept and operator's manual have been updated to represent the as-built subsystem.
- Assess if the shipping plan has been fully implemented.
- Assess if the revised A&I plan has addressed the concerns and recommendations raised by the Detailed Design Review Panel.

At the end of the Delivery Readiness Review, it shall be evident that:

- The selected subsystem is sanctioned for shipping, including any remedial actions required.
- All manufacturing deficits are identified and acknowledged by the PO issued waivers.
- All Configurable Items' configured statuses are updated and verified.

Before proceed to shipping, a supplemental "delta-DRR" may be required to close out remaining issues, if recommended by the Review Panel.

4.4.2 System Manufacturing and Shipping Phase

During the M&S Phase, a combined system MRR/DRR is also planned in advance of the delivery of the first subsystem. The objectives are to demonstrate the PO has the required plans stating the processes and procedures in place to receive and integrate the MSE subsystems.

Table 2 lists the PO documents and their configured statuses for the system MRR/DRR. However, only selected documents within the category: Safety, Operations, Verification, Quality Control and Programmatic form the system MRR/DDR data package, including:

- Health and Safety Plan
- Maintenance Plan
- Spares and Consumables List14
- Assembly and Integration Plan with interim operations plan14
- System Verification Plan
- Product Assurance Plan
- Change Requests Record
- Waivers
- Project Risk Register

Based on the MRR/DRR data package, the Manufacturing/Delivery Readiness Review is conducted to:

- Assess the adequacy of the H&S, verification and PA plans
- Verify if the PO have adequately addressed the concerns and recommendations from the Detailed Design Review Panel, including the usage of system-level Change Requests and subsystem waivers, if applicable, to address design and performance deficiencies.
- Assess if the revised programmatic and technical risks after further risk mitigation since the DDR are deemed complete to begin system integration.
- Assess if the interim operations plan is adequate to begin and support the progress subsystem integration.

At the end of the system Manufacturing/Delivery Readiness Review, it shall be evident that:

- The System is sanctioned to proceed to integration, including any remedial actions required.
- All recognized requirement deficits are acknowledged by the PO via either the Change Control or waiver processes.
- All Configurable Items' configured statuses are updated and verified.

Before proceed to the Assembly, Integration and Verification Phase, a supplemental "delta-MRR/DRR" may be required to close out remaining issues, if recommended by the Review Panel.

4.5 Assembly, Integration and Verification Phase Definition, Expectations and Review Process

The Assembly, Integration and Verification Phase is the final phase of technical development where:

- Subsystems are reassembled, integrated and verified individually after shipping to the post-delivery sites according to their verification plan to prove compliance. A subsystem Final Acceptance Review (FAR) is conducted based on the Final Verification Test (FVT) findings at the end of each subsystem integration activities.
- Provisional on the system A&I plan, subsystems may form partial-systems that are verified before further integration at the system-level. Since the post-delivery site may be the MSE Observatory or at another partner's facility, partial-system FARs are conducted after the findings of their FVTs have been resolved as part of the integration activities at site according to the system verification plan.

- Once fully assembled, the Observatory undergoes System Verification and Science Verification. The system FAR is conducted after the findings of the FVT have been resolved and the final verifications activities scrutinized. This concludes the development of MSE from interim operations to being operationally ready.

Table 3 lists the documents and their configured statuses for the subsystem FAR. However, only selected documents within the category: Verification and Quality Control form the subsystem FAR data package, including:

- Verification Report
- Compliance Matrix
- Product Assurance Report
- Waivers

Table 3 lists the documents and their configured statuses for the partial-system (if applicable) and system FARs. However, only selected documents within the category: Verification and Quality Control form the system FAR data package, including:

- System Verification Report
- Science Verification Report
- Compliance Matrix
- Product Assurance Report
- Waivers

Based on the FAR data package, the Final Acceptance Review is conducted to:

- Confirm the compliance of individual subsystems and the overall System.
- Verify all requirement deficits are identified and acknowledged by the PO issued waivers.

The FAR concludes the AIV Phase. Before entering the Science Validation Phase, a supplemental "delta-FAR" may be required to close out remaining issues of the AIV Phase, if recommended by the Review Panel.

At the end of the Assembly, Integration and Verification Phase, it shall be evident that:

- The subsystem compliances are documented along with the associated waivers with respect to their Level 2 requirements.
- The System compliance is documented along with the associated waivers with respect to the Level 1 requirements.
- The as-delivered system (Level 1) and subsystem (Level 2) document sets are complete.
- All Configurable Items' configured statuses are updated and verified.

4.6 Science Validation Phase Definition, Expectations and Review Process

There may be additional science reviews planned by the Project Scientist and Science Team but they are outside of scope of this management plan currently. They may be added in the future in consultation with the Project Scientist.

The Science Validation Phase is the final phase of MSE development where the Observatory's abilities to conduct and execute surveys are validated in reference with the Design Reference Survey. It is possible that the Science Verification (Level 1) and Science Validation (Level 0) activities are conducted in parallel and share observing time.

Table 1 lists the documents and their configured statuses for the Science Validation Review. However, only the Science Validation Report forms the Science Validation Review data package.

Based on the Science Validation Review data package, the Science Validation Review is conducted to:

- Assess the as-delivered Observatory's abilities to conduct and execute surveys as planned.
- Recommend future development to enhance scientific efficiency.

The Science Validation Review concludes the Project Office's responsibilities and marks the transition of duties to the science operations team. Before entering into science operations, the Review Panel may recommend operations related changes to the science operations team.

At the end of the Science Validation Phase, it shall be evident that:

- The abilities of the as-delivered Observatory to conduct and execute surveys are documented.
- Recommendations from the Review Panel are communicated to the observatory science operations team and the Governing Board.

5. Conclusion

Following the CMRP plan, MSE will transition into steady-state science operations after the Science Validation Phase with a clear understanding of the Observatory's capabilities to meet its science objectives and deliver the envisioned science data products. More importantly, the knowledge and ability to plan strategic improvement based on this understanding will be vital to ensure MSE's ongoing success as a premier astronomical facility.

Appendix A. Planned Project Reviews

1. Conceptual Design Review occurs at the end of Conceptual Design Phase of each subsystem, and a system-level CoDR is also required.
2. Preliminary Design Review occurs at the end of Preliminary Design Phase of each subsystem, and a system-level PDR is also required.
3. Detailed Design Review occurs at the end of Detailed Design Phase of each subsystem, and a system-level DDR is also required.
4. Manufacture Readiness Review occurs before any subsystem enters production during the Manufacturing and Shipping Phase, and a system-level MRR is also required.
5. Delivery Readiness Review occurs after a subsystem's Factory Acceptance Test before it is approved for shipment at the completion of the Manufacturing and Shipping Phase, and a system-level DRR is combined with the system-level MRR.
6. Final Acceptance Review at three levels:
   a. Subsystem-level FAR occurs once a post-delivery subsystem has undergone its Final Verification Test after reassembled according to the subsystem's assembly and integration plan in the Project's Assembly, Integration and Verification phase. The FVT is executed based in the subsystem's verification plan, and FAR is conducted after the findings of the FVT have been resolved in the subsystem's verification report.
   b. Partial-system level FAR occurs after a partial-system has undergone its FVT. A partial-system is an integrated ensemble of selected subsystems, which have passed their individual FARs, as dictated by the system-level (Level 1) assembly and integration plan in the Project's AIV phase. The FVT is executed based on the system-level verification plan for each partial-system, and the FAR is conducted after the findings of the FVT have been resolved in the System's verification report for each partial-system.
   c. System-level FAR is required at the end of the Project's AIV phase to assess the System and science verifications findings based on their individual verification plans and reports. The System is assembled from subsystems and partial-systems, which have undergone their individual FARs, according to the system-level assembly and integration plan. The FVT is executed based in the system-level verification plan, and a Science Verification Test is conducted based in the science verification plan. The FAR is conducted after the findings of the FVT and Science Verification Test have been resolved in the system verification report and science verification report.
7. Science Validation‡ that occurs at the end of the Science Validation Phase following the Science Validation Test. The Science Validation review is the final review after which the Observatory transitions to science operations

‡ There may be additional science reviews organized by the Project Scientist and the Science Team. These science reviews are outside the scope of the CMRP currently. They may be incorporated in the future in consultation with the Project Scientist.

Appendix B. Document Types

The nature of the document reflects the purpose of the document, and it is organized into 13 types that are described as follows:

- **DWG:** Technical drawings, such as mechanical drawing, electrical drawing, software flow chart or architectural drawing, etc., in PDF format. The associated computer aided design files are managed in their native formats by their own specialized design software.
- **ICD:** Interface Control Documents defining the interface design requirements between two systems.
- **MEE:** Meeting related documents associated with the planning and execution of formal meetings such as system-level and subsystem-level reviews, etc.
- **MGT:** Management documents relating to managerial aspects such as costing, contracts, call for bids, risk registers, Work Breakdown Structure Dictionary, and work package agreements, etc., with the exception of schedules which has its own type.
- **MOD:** Computer aided design models and/or simulation files such as Zemax, Mathcad or ANSYS FEA files, etc. The MOD files are deposited in Docushare for Configuration Management purposes.
- **PLA:** Science, technical, safety, operations or managerial plans; or documents describing procedures such as a maintenance procedure, calibration procedure or an observing procedure.
- **RPT:** Documents stating the status of the System or subsystem, or containing findings, conclusions and recommendations, or capturing technical analysis of particular topic under examination.
- **REQ:** Documents stating the performance, functional and operational requirements of the system or a subsystem.
- **SCH:** Documents outlining the chronological progression of events and/or milestone information associated with the developmental timeline of the system or a subsystem. For example, a PDF document extracted from the Project's Microsoft project plan.
- **SPE:** Specifications related to a purchased item containing its composition, design description, stated functions and/or performance, e.g., material datasheet.
- **STD:** Documents stating the requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their intended purpose. Standards are often established by an external authorities for product assurance purposes.
- **SYS:** Systems engineering documents such as performance budget, configuration index document, compliance matrix, change request, waiver, and verification cross-reference etc.

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