MARC-60 and Propulsion System Collaboration Status Meeting

(MARC-60 = Mitsubishi Aerojet Rocketdyne Collaboration – 60 klbf engine)

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Contents

MARC-60 and Propulsion System Study Topics

Technical

- Liquid Hydrogen Interface Conditions
  - Determine the best system-level solution for engine interface NPSP
  - Determine the resulting engine architecture (boost pump or no boost pump)
- Valve Actuation
  - Determine best valve actuation approach for NASA version of engine: electromechanical actuators (EMAs) or pneumatic actuators
  - Determine resulting requirements and development plan impacts due to valve actuation method choice
- Propulsion System Elements
  - Determine what main-propulsion-system subsystems could be or should be incorporated into the scope of the collaboration activity
- Technical Standards
  - Implementation of imposed NASA standards
  - Resolution/mitigation for lingering technical issues
- Delta Certification Definition
  - Definition of the appropriate scope for delta certification effort
  - Testing facility needs and costs
  - Controller development, qualification, and integration plan

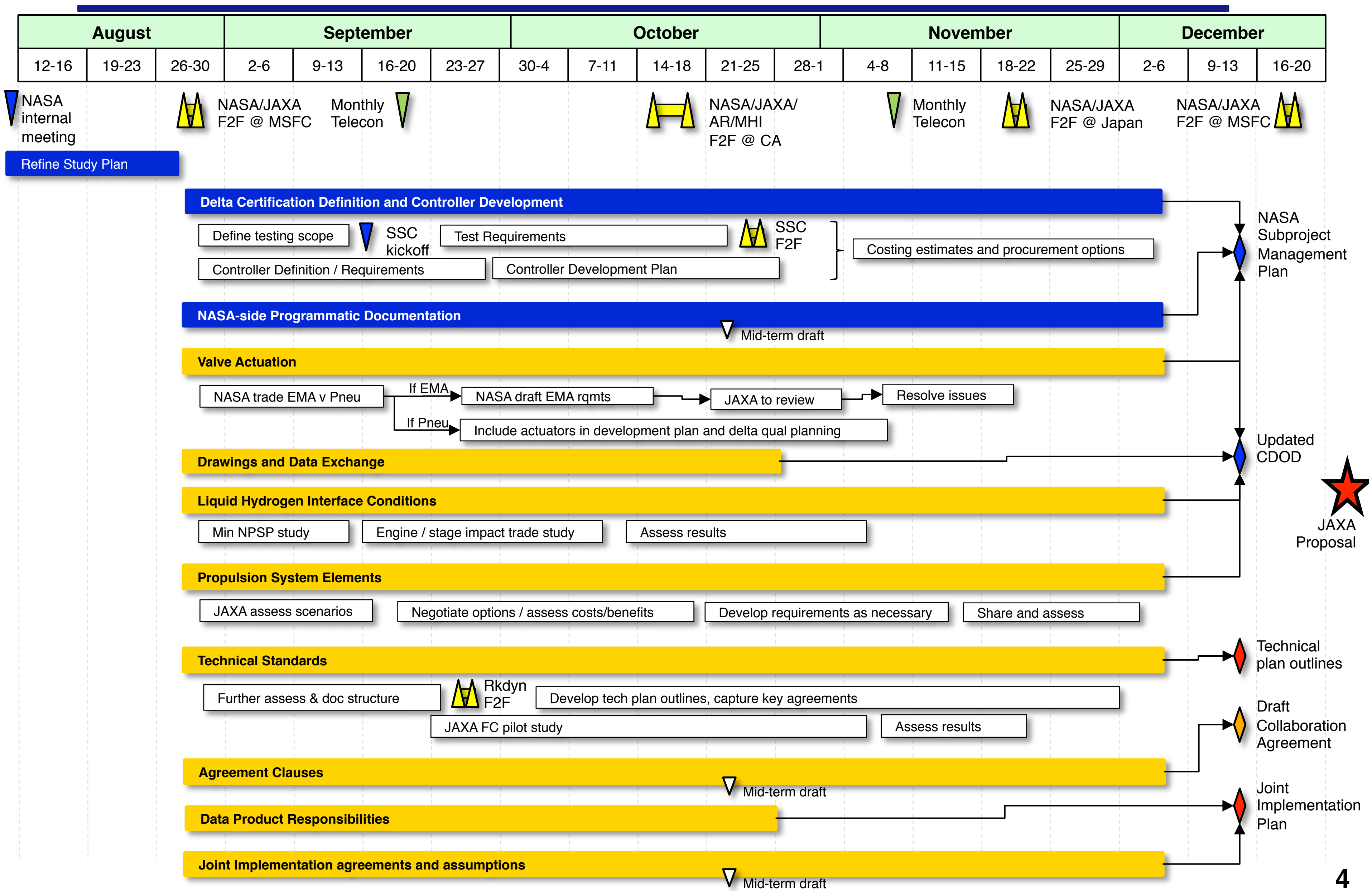
Programmatic

- Agreement Clauses
  - Resolve various agreements that will need to be part of the instrument to be used between NASA and JAXA (memorandum of understanding or international space act agreement) including intellectual property and licensing considerations
- Drawings and Data Exchange
  - Resolve issue with regards to what can or will be delivered in terms of engine drawings
- Data Product Responsibilities
  - Roles and responsibilities for specific data products split up in a way similar to split of hardware between MHI and Rocketdyne
- NASA-side Programmatic Documentation
  - Develop MARC-60 Subproject Management Plan
- Joint Implementation Plan
  - Develop joint agreements and assumptions

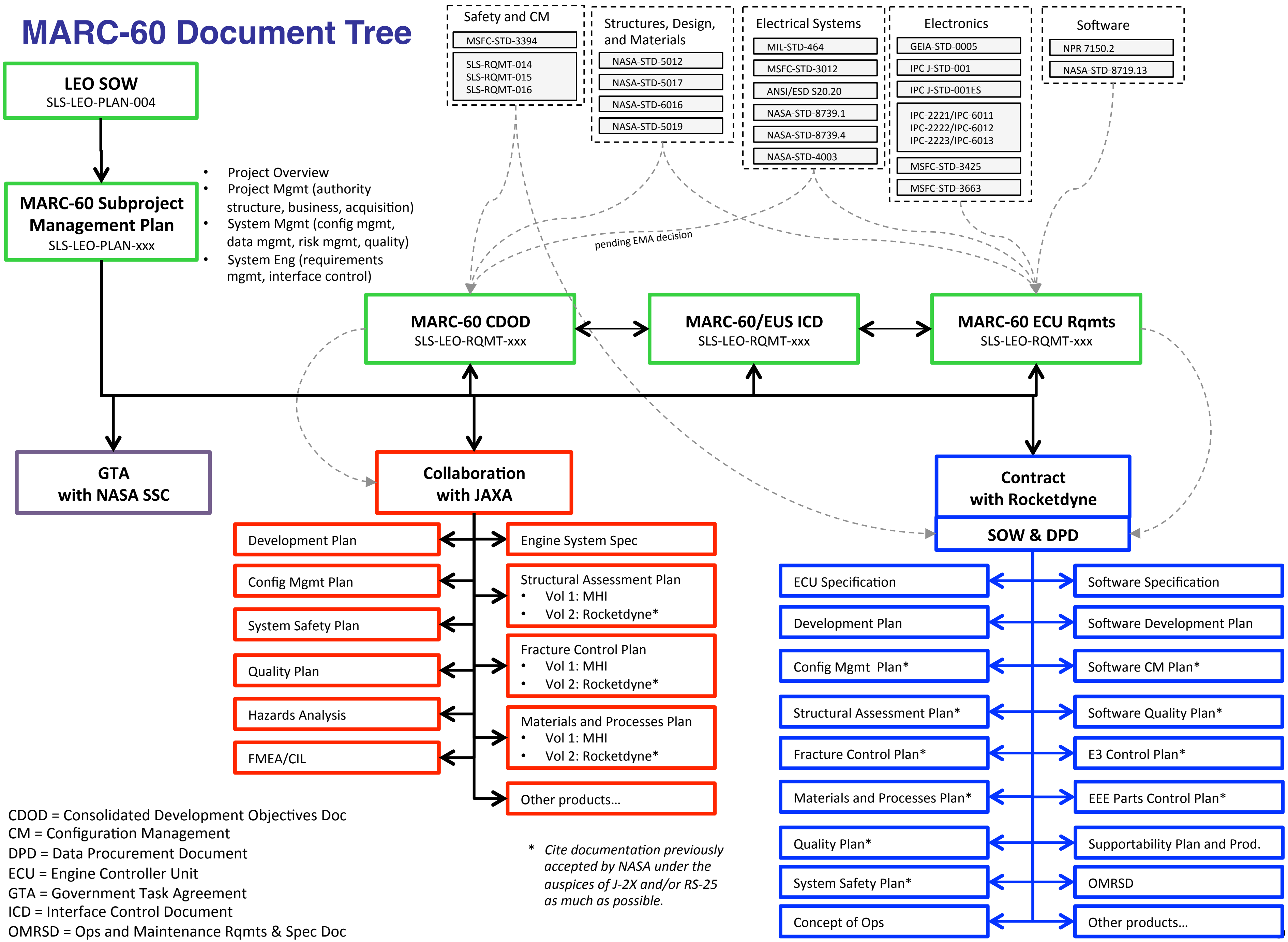
Key:
Joint NASA & JAXA activity
Primarily a NASA activity
Primarily a JAXA activity

See Backup Section #1 for further descriptions of these topics

MARC-60 and Propulsion System Study Schedule



MARC-60 Document Tree



CDOD = Consolidated Development Objectives Doc
CM = Configuration Management
DPD = Data Procurement Document
ECU = Engine Controller Unit
GTA = Government Task Agreement
ICD = Interface Control Document
OMRSD = Ops and Maintenance Rqmts & Spec Doc
SOW = Statement of Work

MARC-60 Subproject Management Plan – Draft Outline

1. **Introduction**
   - Purpose
   - Scope
   - Precedence
   - Implementation

2. **Reference Documents**

3. **Subproject Overview**
   - Objectives
   - Development
   - Production and Operations

4. **Subproject Management**
   - Authority and Documentation
   - Management Structure
   - Business Management
   - Acquisition Planning
   - Facilities Development
   - Insight and Engagement

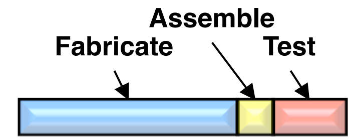
5. **System Management**
   - Configuration Management
   - Quality Assurance
   - Risk Management
   - Export Control
   - Data Management

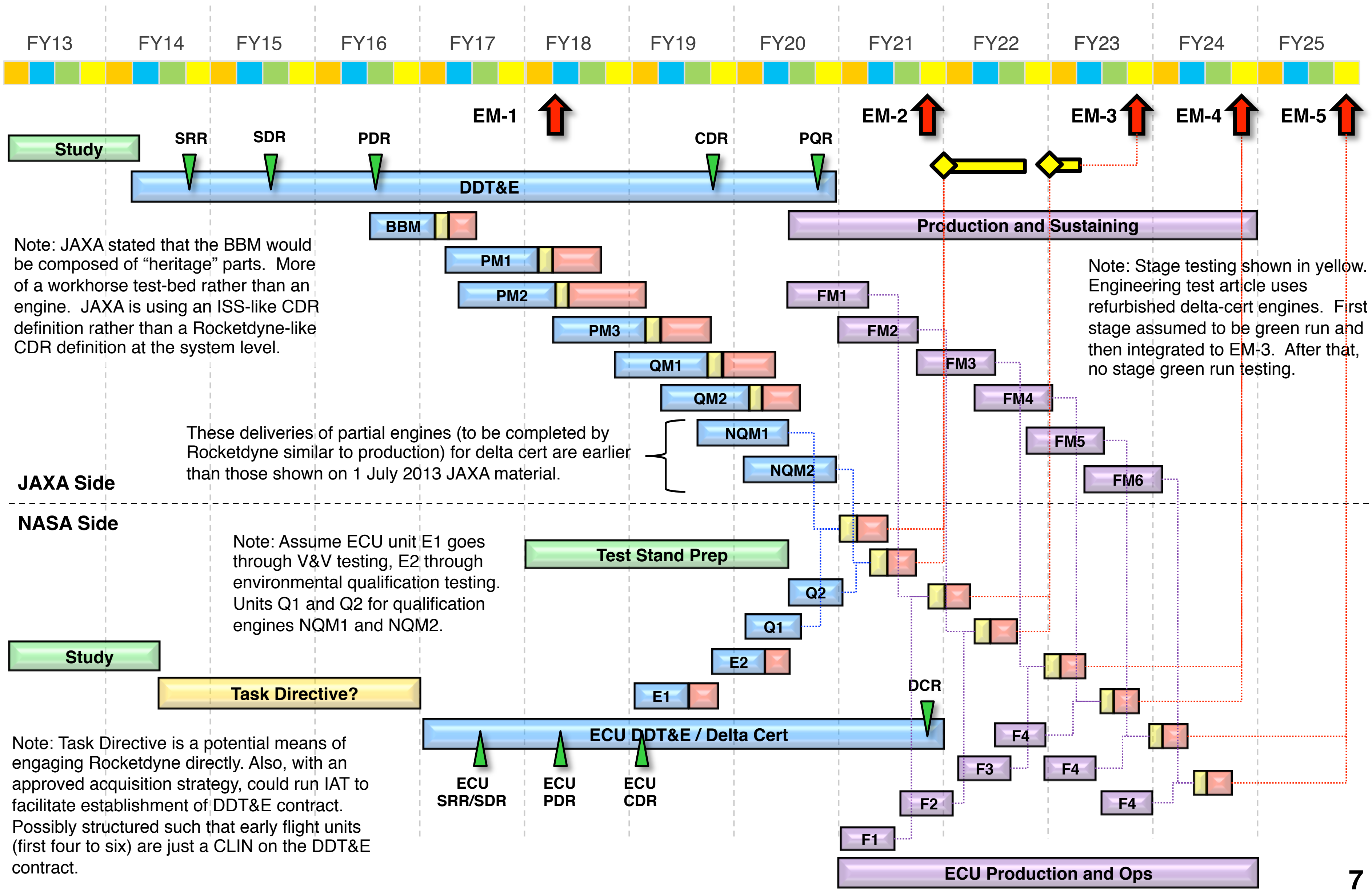
6. **System Engineering**
   - Requirements Management
   - Verification Process
   - Compliance Validation
   - System Analysis
   - System Reliability and Safety
   - System Integration
   - Interface Control
   - System Certification

See Backup Section #2 for notes regarding content each of these proposed plan sections

MARC-60 Long-Term Development Plan

(updated: consistent with 1 July JAXA material and outer loop TIM material)





Backup Section #1 – Details Regarding Study Elements

Liquid Hydrogen Interface Conditions

- **Issues to be Addressed**
  - Determine the best system-level solution for interface NPSP
  - Determine the resulting engine architecture (boost pump or no boost pump)
- **Key Participants**
  - NASA: engine systems, turbomachinery, advanced concepts
  - JAXA: (same)
- **Approach**
  - NASA and JAXA to determine reasonable lowest accepted NPSP for no-boost pump architecture (mid-September)
  - NASA and JAXA to perform separate parametric cost-benefit assessment at the stage level for lower NPSP point(s)
  - Share parametric assessment results by mid-November
  - Update CDOD as appropriate
- **Desired Outcome**
  - Corrected requirement definition
  - Defined baseline engine architecture
  - Results documented in updated CDOD by late-November and then in the JAXA proposal to follow

Valve Actuation

♦ Issues to be Addressed

- Determine what is the best valve actuation approach for NASA version of engine: electromechanical actuators (EMAs) or pneumatic actuators
- Determine resulting requirements and development plan impacts due to valve actuation method choice

♦ Key Participants

- NASA: engine systems, valves and mechanisms branch, S&MA
- JAXA: (same)
- Rocketdyne (if necessary)

♦ Approach

- Internal to NASA, determine cost/benefit for sticking with EMAs provided by JAXA or going to pneumatic actuation as part of delta-certification (work with Rocketdyne if necessary) (mid-September)
- If the decision is to stick with EMAs, define redundancy requirement and compliance approach (mid-November)
- If the decision is to go with pneumatics, define development plan and estimate costs (mid-November)
- Share results with JAXA and address any further issues
- Update CDOD as necessary

♦ Desired Outcome

- Baseline valve actuation method
- Defined requirements and/or development effort consistent with actuation method
- Results documented in updated CDOD by late-November and then in the JAXA proposal to follow

Propulsion System Elements

♦ Issues to be Addressed

- Determine what main-propulsion-system subsystems could be or should be incorporated into the scope of the collaboration
- Such subsystems could include thrust vector control, propellant pre-valves, pneumatic systems (purge and/or actuation), thrust frame

♦ Key Participants

- NASA: engine systems, MPS folks, ACO
- JAXA: (same)

♦ Approach

- Determine approach for propulsion system collaboration
  - Two-engine propulsion module
  - Single-engine propulsion module
  - Semi-stage including LOX tank
  - Individual system pieces (i.e., JAXA as vendor)
- NASA to provide first-cut definition of different options and supply this to JAXA (by mid-September)
- Negotiate back and forth until definition solidifies (by mid-November)
- Update CDOD as necessary

♦ Desired Outcome

- Clear definition of scope with regards to what subsystems are to be part of this development effort
- Results documented in updated CDOD by late-November and then the JAXA proposal to follow

Technical Standards

- **Issues to be Addressed**
  - Implementation of:
    - NASA-STD-5012, structural design and assessment
    - NASA-STD-5017, mechanism design
    - NASA-STD-5019, fracture control
    - NASA-STD-6016, materials and processes
  - Specific lingering technical issues
  - Documentation approach (e.g., proposal for separate MHI and Rocketdyne volumes)
- **Key Participants**
  - NASA: project folks, key technical representatives from engineering, S&MA
  - JAXA: project folks
  - Rocketdyne & MHI
- **Approach**
  - Work with programmatic parties (NASA, JAXA, Rocketdyne, MHI) regarding appropriate documentation (and responsibility) structure (mid-September)
    - Must take into account ITAR considerations
  - For fracture control, pursue JAXA's plan for a pilot study regarding injector design and assessment
  - For other standards, have technical experts talk directly (with an ITAR referee present)
    - This would be really good to have truly face-to-face although that may obviously represent logistical issues
    - Could we do this at some "middle ground" such as at the Rocketdyne facility in California?

  - (continued on next page)

Technical Standards (continued)

- **Approach (continued)**
  - Develop technical design plan outlines with consensus decisions documented. These ought to be the starting points for what will become the plans identified in the CDOD for insight purposes (by mid-December)
    - Chiefly concerned with JAXA/MHI side as opposed to Rocketdyne side
  - NASA S&MA (in conjunction with NASA engineering) to perform risk assessments for any place where agreement cannot be achieved (by mid-December)
- **Desired Outcome**
  - Agreed to documentation structure with regards to technical design and assessment plans
  - Preliminary outlines for design and assessment plans fleshed out with consensus agreements
  - Risk assessments for items where consensus was not achieved
  - Technical plan outlines containing consensus agreements and associated risk assessments by mid-December

Delta Certification Definition

- **Issues to be Addressed**
  - Definition of the appropriate scope for delta certification effort
  - Testing facility needs and costs
  - Controller development, qualification, and integration plan
- **Key Participants**
  - NASA: MSFC (engine systems), SSC
  - Rocketdyne
- **Approach**
  - This is primarily a NASA-side study with the assistance of Rocketdyne as necessary
    - However, JAXA should be informed of preliminary decisions to ensure that they are consistent with overall development plan
  - Joint meeting with SSC representatives regarding test facility options and cost estimates (September?)
  - Meeting with Rocketdyne regarding controller plans and associated ROM costs to inform budget planning (in conjunction with face-to-face JAXA meeting in October?)
- **Desired Outcome**
  - Engine delta-certification plan including test facilities identified and ROM costs
  - Controller development, qualification, and integration plan with ROM costs
  - Results captured in NASA-side program management documentation (mid-November)

Agreement Clauses

- **Issues to be Addressed**
  - Resolve various agreements that will need to be part of the instrument to be used between NASA and JAXA (memorandum of understanding or international space act agreement)
  - One in specific is intellectual property and licensing considerations
  - Other issues?
- **Key Participants**
  - NASA: procurement, legal, program office
  - JAXA
- **Approach**
  - NASA to formulate draft agreement document (mid-October)
  - Review and comment by JAXA
  - Meeting between the parties to resolve issues (mid-November)
  - Update draft agreement (mid-December)
- **Desired Outcome**
  - Draft agreement document effectively ready to go should decisions at higher levels head that way

Drawings and Data Exchange

- **Issues to be Addressed**
  - Disagreement with regards to what can or will be delivered in terms of engine drawings
  - JAXA states that actual design drawings cannot be delivered to NASA (due to export control and proprietary data issues)
  - NASA needs drawings to some level for the purposes of development insight and stage integration
  - General issue of data exchange: developing and exercising the process
- **Key Participants**
  - NASA: ACO, engineering
  - JAXA
  - Rocketdyne and MHI?
- **Approach**
  - This can probably be resolved with a meeting and an understanding of needs, restrictions, and concerns
- **Desired Outcome**
  - Updated data delivery requirements
  - Results documented in updated CDOD by mid-November and then the JAXA proposal to follow

Data Product Responsibilities

- **Issues to be Addressed**
  - While a listing of responsibilities for the work scope regarding hardware has been split up between MHI and Rocketdyne, a similar split has not been shown regarding other products
  - There would appear to be some natural affinities for Rocketdyne in dealing with NASA processes and it would be good to identify these upfront to clarify expectations.
- **Key Participants**
  - NASA
  - JAXA
  - Rocketdyne / MHI
- **Approach**
  - JAXA should first formulate the proposed split of primary responsibility for data products.
    - There are a few items that would seem to be most naturally for Rocketdyne.
    - This obviously needs to include Rocketdyne and, probably, MHI in the formulation
  - NASA to review
  - Discuss in meeting and come to resolution
- **Desired Outcome**
  - Listing for data products analogous to the hardware division of primary responsibility as part of updated JAXA proposal

NASA-side Programmatic Documentation

- **Issues to be Addressed**
  - Management approaches from the NASA perspective including such things as:
    - project management
    - requirements management
    - business management and procurement
    - configuration and data management of products and outputs
    - engineering, safety, and quality assurance insight and engagement processes
    - interface control
  - Development plan from NASA perspective (rolling in results from delta-certification definition task)
  - Capture decisions made during this study period within this process
- **Key Participants**
  - NASA: ADO, XP20, engine systems
- **Approach**
  - Typical document development process
    - Develop draft
    - Put out for review
    - Iterate until ready for control board approval
  - Provide to JAXA to ensure consistent with expectations
    - Discuss as necessary
- **Desired Outcome**
  - Foundational program management documentation baselined

JAXA-side Programmatic Documentation

- **Issues to be Addressed**
  - Effectively the same issues addressed within the NASA-side programmatic documentation but from the JAXA perspective
  - Joint Implementation Plan
- **Key Participants**
  - JAXA
  - Rocketdyne
  - MHI
- **Approach**
  - JAXA to develop and share with NASA to ensure consistency with expectations
  - Discuss as necessary
- **Desired Outcome**
  - Establishment of a draft joint implementation plan representing program management processes to be implemented at JAXA

Backup Section #2 – Annotated Subproject Management Plan Outline

Draft Annotated Outline for NASA MARC-60 Subproject Plan

1. Introduction

- Purpose: Statement of the reason for this document to exist.
- Scope: Cite here the pieces of the LEO SOW that pertain to this effort. These should provide the top-level scope.
- Precedence: Where this document stands with regards to governing authority relative to other documents.
- Implementation: Responsibility and process for enacting and updating this document.

2. Reference Documents

3. Subproject Overview

- Objectives: This is an expansion of the scope as described in Section 1. It provides an overview of the subproject in terms of parties involved and the timeline.
- Development: How development to be conducted. Roles and responsibilities for the different parties. Lines of communication. Schedule.
- Production and Operations: Projected process for supporting a regular flight manifest. Roles and responsibilities.

4. Subproject Management

- Authority and Documentation: How this subproject falls within the larger structure of the engines element and the governing program. Top-level documentation tree including linkages to higher level documentation.
- Management Structure: Management structure. Internal org chart. Individual office roles and responsibilities. It is not expected that there will be a separate management structure within LEO for this subproject so the focus here is how this fits in with the LEO structure and how ADO is involved as well.
- Business Management: Discussion of where this subproject gets funding for the different parts. Discussion of NASA funding via the PPBE process. Responsibilities for schedule maintenance and integration across various parties.
- Acquisition Planning: Vision and planning for acquisition process related to the separate pieces of the overall effort. Include some discussion regarding the international space act agreement. Contract phasing and scope.
- Facilities Development: Planning regarding facilities, particularly assembly and testing facilities. Will have to work with SSC to development this plan.

Draft Annotated Outline for NASA MARC-60 Subproject Plan (continued)

4. Subproject Management (continued)

- Insight and Engagement: Present here the plan for insight and engagement, particularly focusing on the unique aspects of this subproject in dealing JAXA leading the largest portion of the activity across two contractors.

5. System Management

- Configuration Management: Process for establishing, maintaining, and controlling project baseline. Technical and programmatic review board structure. It is assumed that CM for MARC-60 will be the same as that for RS-25 and J-2X and so this section should only note differences from the established LEO CM Plan.
- Quality Assurance: Responsibilities for quality assurance and applicable standards. The focus here ought to be unique structures for this subproject or deviations from those processes governing RS-25 and J-2X quality management.
- Risk Management: Process for risk identification, ranking, tracking, and mitigation. Again, focus is how this is different than mainline LEO activities (if at all).
- Export Control: Given the nature of this activity in dealing with JAXA, this section will have some significance. Describe clearly the general rules and the specific processes to be followed in dealing with JAXA. Identify key points of contact for the various steps in the process and for gaining further information and guidance.
- Data Management: Identification of official data repositories (raw data and subproject documentation).

6. Systems Engineering

- Requirements Management: Illustrate the process for levying requirements across two contractors (and through JAXA) and how these requirements interact with interfaces and environments.
- Verification Process: Top-level description of the process for verification including planning and compliance documentation requirements.
- Compliance Validation: Process for handling compliance to applicable design, construction, and workmanship standards. Of significance here are the differences between how to treat Rocketdyne versus how to deal with JAXA/MHI.
- System Analysis: Responsibilities for systems analysis. Also, the process for the identification and control of critical math models to support integration.

Draft Annotated Outline for NASA MARC-60 Subproject Plan (continued)

- **Systems Engineering (continued)**
  - System Reliability and Safety: Processes for the development of key reliability and safety products. Focus here on responsibilities and any differences between this subproject activity and mainline LEO efforts.
  - System Integration: Describe interaction with stage development and overall program. Given that the stage development effort does not yet exist, this section will, for now, have to describe how the subproject functions in this environment.
  - Interface Control: Describe the process for ICD development and maintenance. In the interim prior to the establishment of a stage development effort, describe how this will be handled on the engine side alone.
  - System Certification: Necessary constituents for a design certification review at the end of the development effort.