

**Multi-Purpose Crew Vehicle (MPCV)
Independent Verification and Validation (IV&V)
Project Execution Plan (IPEP)
Fiscal Year 2016**

IV&V PROJECT EXECUTION PLAN

DOCUMENT COORDINATION and APPROVALS

This is Version 5.1 of the Multi-Purpose Crew Vehicle IPEP. Changes to the body of this document (Sections 1-4) will trigger an increase in the version number (i.e., Version 6.0) and subsequent review/approval and concurrence by all entities listed below. This IPEP will be revisited and updated as necessary on a semi-annual basis. At a minimum, a new version of this IPEP will be published each fiscal year and the version number will be increased by one (e.g., Version 6.0). Any revisions made to Appendices only of this IPEP will result in an update to the number to the right of the decimal (e.g., Version 5.2). Draft versions of the IPEP will be marked as "DRAFT."

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* Indicates concurrence with Sections 1-4 of the IPEP.

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If any process in this document conflicts with any document in the NASA Online Directives Information System (NODIS), this document shall be superseded by the NODIS document. Any reference document external to NODIS shall be monitored by the Process Owner for current versioning.

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1 Introduction

1.1 Document Organization

The IPEP is divided into two major parts: the body of the document and its appendices. The sections within the document body focus generically on the “rules of engagement” that will be followed by the IV&V Team and the Multi-Purpose Crew Vehicle Program over the course of the Program lifecycle. Specifically, the IPEP includes the basic tenets for an agreement between the IV&V Team and the Program, including the roles and responsibilities, communications paths, and artifacts anticipated to be shared between the organizations. It is expected that these data are rather static and, once agreed upon, will not change significantly during any single year.

The second part of the document, the appendices, focuses more on the fiscal year activities for the IV&V efforts. The appendices contain data that are more dynamic in nature and are expected to change over the course of the Program’s lifecycle. The appendices include the results of the IV&V Heritage Review, IV&V Portfolio Based Risk Assessment (PBRA) data and subsequent Risk Based Assessments (RBA), focus of IV&V Technical Scope and Rigor data and detailed information for each planned execution year (including items such as IV&V goals/objectives, required resources, schedule, and risks).

From this point forward, the Multi-Purpose Crew Vehicle Program will be referred to as “the Program.”

1.2 Document Purpose

The purpose of this IPEP is two-fold. First, it is to communicate IV&V interactions, interfaces, roles and responsibilities, technical products, and reporting methods with the Program. Second, the IPEP serves as the operational document for the IV&V efforts. The IPEP is prepared and maintained by the IV&V Project Manager (PM). The IV&V PM coordinates the creation and maintenance of this document with affected individuals and organizations (within the NASA IV&V Program as well as with the Program).

In signing the document, the Program personnel understand that their concurrence signature reflects the agreements identified within the body of the document, excluding the appendices. Signatures of NASA IV&V personnel reflect their understanding of the entire document, appendices included.

This IPEP will be in effect from the signing thereof until completion of the IV&V efforts for the Program or until terminated at the request of the NASA IV&V Program or the Program.

1.3 Intended Audience

The intended audience of this document includes entities within the NASA IV&V Program as well as within the Program. Entities within the NASA IV&V Program include the NASA IV&V Project Manager and IV&V Office Management. Entities within the Program that this IPEP is intended for include the Program Manager, the MPCV Software Manager (who is also the primary IV&V Point of Contact), the MPCV Avionics/Power/Software Manager, and the MPCV

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Chief Safety Officer (CSO) (who is also the Safety and Mission Assurance Manager for the MPCV Program Office) and Information Security personnel.

2 IV&V Overview

2.1 IV&V Goals and Objectives

The IV&V Team will conduct independent, verification and validation analyses to ascertain “goodness of product” for the Program’s system software. Validation-related analysis will allow the IV&V Team to evaluate the Program’s development artifacts to ensure that the “right behaviors” have been defined in the artifacts. “Goodness of product” and the “right behaviors” are those attributes, features and qualities that adequately describe what the system is supposed to do, what the system is not supposed to do, and what the system is supposed to do under adverse conditions. These attributes, features and qualities address the NASA IV&V Three-Questions of the Program’s mission software defined in the NASA IV&V System Level Procedure (SLP) [IV&V 09-1](#), *Independent Verification and Validation Technical Framework*. The NASA IV&V three-questions are:

1. *Does the software do what it is supposed to do?*
2. *Does the software not do what it is not supposed to do?*
3. *Does the software respond appropriately under adverse conditions?*

The validation-related analysis performed will strive to ensure that the system software performs to the user’s needs under operational conditions. Verification-related analysis will allow the IV&V Team to determine whether the products of each development activity fulfill the requirements or conditions imposed by a previous development activity.

2.2 IV&V Approach

The IV&V Team functions technically, managerially, and financially independent of the Program. The IV&V approach will consist of verification- and validation-related analysis. Verification and validation are described further below, including the artifacts generally required for specific analysis objectives. For additional information regarding verification- and validation-related analyses, see SLP [IV&V 09-1](#), *Independent Verification and Validation Technical Framework*.

Where possible all independent verification and validation activities will be integrated across the technical framework elements to: (a) take advantage of the Program’s maturity, (b) provide the highest quality value added engineering analyses, and (c) leverage completed Exploration Flight Test -1 (EFT-1) analysis to the assurance of Exploration Mission 1 and 2 (EM-1/2).

2.2.1 Verification and Validation

Specific analyses that the IV&V Team may perform include verification and validation (V&V) of: Concept Documentation, Requirements Documentation, Design Documentation, Test Documentation, Implementation, and Operations and Maintenance Content. The IV&V Team may also perform independent testing that may use simulators, test environments, and/or other test systems provided by either the IV&V Program or the MPCV Program.

IV&V analyses are intended to provide evidence based assurance that selected integrated Human Exploration and Operations – Exploration Systems Development (HEO-ESD) systems and software will perform as required under nominal and defined off-nominal conditions or the risks are documented and delivered to the Programs affected. The systems examined will include MPCV, other HEO-ESD Programs receiving IV&V coverage (i.e., the Ground Systems Development and Operations [GSDO] and the Space Launch System [SLS]), and the interfaces to and from major related systems such as command sources, control centers, or major communication links.

Examples of artifacts the IV&V Team needs to accomplish these analyses are depicted in Table 2-1. For the IV&V efforts, the IV&V Team anticipates that these artifacts are necessary to support verification-and-validation related analyses. In the event that any of these artifacts cannot be provided to the IV&V team, and/or the IV&V analyses are required to be performed on-site at the development organization, the IV&V PM and the IV&V Point Of Contact (POC) will closely coordinate impacts to the technical work as well as cost and schedule. The IV&V team does not drive or mandate the creation of specific software artifacts, but will work with available information and content in most formats, as long as the artifacts provided includes the data necessary to verify and validate the developer's software, and to draw credible assurance conclusions on the software's mission suitability.

Results of the verification and validation will serve as a basis for assessing the goodness of the Program software in terms of the capabilities delineated in the IV&V PBRA Results. These capabilities are assessed with respect to the Program's mission success criteria and the software's ability to perform and/or support expected system/software behaviors.

The typical outputs of the V&V related analyses will include requirements analysis reports, test design analysis reports, build analysis reports, and issues and risks. Refer to Section 4 of this document for additional information on these products.

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Table 2-1: Program Targeted Verification & Validation Artifacts

Artifact Name	Need/Applicable Analysis	Use/Comments
Rhapsody Model and MATLAB Models and Code	<p>“Determine Reuse Applicability by Manually Comparing Operational Environments”</p> <p>“Verify Software Design by Inspecting Traces to Requirements and Software Architecture”</p> <p>“Verify Software Interface Design by Inspection Against Interface Requirements”</p> <p>“Verify Software Implementation by Inspecting Traces to Requirements”</p>	<p>Live repository access and use of the live repository in IV&V Technical Framework (TF) 5 Design and TF 6 Implementation V&V supports “in-sync” integrated design and code analysis and their use was demonstrated during the EFT-1 IV&V project. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>
Source Code	<p>“Verify Software Code Quality using Static Analysis Tools”</p>	<p>Program source code for defined releases provides the essential synchronization of IV&V static analyses and Program Flight Software (FSW) development, supporting Development Integration Issue Record (DIIR) submission.</p>
Software Test Report (STR)	<p>“Verify Test Execution by Inspection of Test Cases, Inputs and Results”</p>	<p>The STR provides test results that document the execution of the test. The STR also documents the associated DIIRs, Software Requests (SRs) or other off nominal conditions driving regression testing. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>

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Artifact Name	Need/Applicable Analysis	Use/Comments
System and FSW Requirements including Dynamic Object Oriented Requirements System (DOORS) database requirements, Cradle requirements database Software requirements reports Software requirements specifications. Requirements Trace Data NASA-STD-8719.13 Section 5.7.1 safety critical requirements trace information. <redacted>	“Verify Software Implementation by Inspecting Traces to Requirements” “Verify Software Interface Design by Inspection Against Interface Requirements” “Verify Software Design by Inspecting Traces to Requirements and Software Architecture” “Validate Test Procedures by Inspection and Traces to Requirements” “Validate Test Cases by Inspection and Traces to Requirements” “Validate Test Plan by Inspection” “Validate Safety Requirements by Inspection of Traces to Fault Trees and FMEA” “Validate Requirements by Inspecting Against Quality Criteria and System/Software Background Artifacts” “Validate Requirements by Inspecting Bidirectional Traces” “Validate System Security Categorization and Regulatory Security Requirements by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 1)” “Verify Security Control Selection and Threats/Risks Identification by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 2)” “Validate Software Architecture by Inspecting Traces to Essential Properties” “Validate Interface Requirements by Inspection Against Component Interfaces”	FSW requirements validation is performed under IV&V TF 3. Requirements are analysis targets or reference artifacts in nearly all TF elements. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.

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Artifact Name	Need/Applicable Analysis	Use/Comments
Software Design Documents (SDDs)	<p>“Validate Software Architecture by Inspecting Traces to Essential Properties”</p> <p>“Determine Reuse Applicability by Manually Comparing Operational Environments”</p> <p>“Verify Software Design by Inspecting Traces to Requirements and Software Architecture”</p> <p>“Verify Software Interface Design by Inspection Against Interface Requirements”</p> <p>“Verify Software Implementation by Inspecting Traces to Requirements”</p>	<p>EFT-1 used the live repositories and did not use software design documents; this practice will continue forward in EM-1/2.</p> <p>Software design documents provide model views and narrative elements missing from the live repositories. SDDs are alternative sources of information also found in the live repositories.</p>
Interface Control Documents (ICDs)	<p>“Validate Requirements by Inspecting Against Quality Criteria and System/Software Background Artifacts”</p> <p>“Verify Software Interface Design by Inspection Against Interface Requirements”</p> <p>“Verify SW Interface Implementation by Inspection Against Interface Design”</p>	<p>ICDs are used in validation and verification analysis performed under IV&V TF 3.4, TF 5.4 and TF 6.3.</p> <p>ICDs define subsystem component interface protocols for communication to and from external systems and customers</p>
Use Cases	<p>“Validate Mission Project Operational Concepts by Generating Use Cases from Concept Documentation”</p> <p>“Validate Requirements by Inspecting Against Quality Criteria and System/Software Background Artifacts”</p>	<p>Use cases elaborate the planned application of the system and FSW, supporting the validation of the requirements.</p> <p>The CONOPS validation is also supported via Use Case and CONOPS consistency.</p>

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Artifact Name	Need/Applicable Analysis	Use/Comments
<p>Concept of Operations (Needs Goals and Objectives [NGOs])</p>	<p>“Validate System Security Categorization and Regulatory Security Requirements by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 1)”</p> <p>“Verify Security Control Selection and Threats/Risks Identification by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 2)”</p> <p>“Validate Requirements by Inspecting Against Quality Criteria and System/Software Background Artifacts”</p> <p>“Validate Mission Project Operational Concepts by Generating Use Cases from Concept Documentation.</p>	<p>CONOPS (or NGOs) drive system functions, behaviors and requirements.</p> <p>These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>
<p>Analysis Reports, Trade Studies</p>	<p>“Validate Feasibility Study Conclusions by Inspection”</p>	<p>Support for concept validation</p>
<p>Fault Trees, Preliminary Hazard Analyses (PHAs), Hazard Analyses (HAs), Failure Modes & Effects Analyses (FMEAs)</p>	<p>“Validate Safety Requirements by Inspection of Traces to Fault Trees and FMEA”</p> <p>“Validate Test Cases by Inspection and Traces to Requirements”</p> <p>“Verify Software Behavior for Off-Nominal Conditions using Independent Testing”</p> <p>“Validate Software Architecture by Inspecting Traces to Essential Properties”</p>	<p>Safety critical software requirements, design, implementation and test are all traced from system hazards.</p> <p>System hazards provide the basis for validation of requirements, design, implementation and test. Hazards provide a source of IV&V Question 2 and Question 3 behaviors. Question 2 and Question 3 behaviors can be a significant source of independent test cases. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>

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Artifact Name	Need/Applicable Analysis	Use/Comments
Master Verification Plan	“Validate Test Cases by Inspection and Traces to Requirements” “Validate Test Plan by Inspection” “Validate Test Procedures by Inspection and Traces to Requirements”	The Master Verification Plan (MVP) provides the structure in which all FSW testing is performed. The MVP also defines the verification activities related to and encompassing the Avionics Subsystem, including flight and flight support software as well as component hardware (including Guidance Navigation & Control (GN&C) hardware components). The MVP defines the requirements to be verified, and for each requirement identifies: (a) the success criteria, (b) the verification events, (c) the Verification Information Sheets, and the (d) verification status.
Software Test Description (STD)	“Validate Test Cases by Inspection and Traces to Requirements” “Validate Test Plan by Inspection” “Validate Test Procedures by Inspection and Traces to Requirements”	The MPCV STD provides <ul style="list-style-type: none"> • verification criteria for each test • updated software test case material.
Software Test Procedure (STP)	“Validate Test Cases by Inspection and Traces to Requirements” “Validate Test Plan by Inspection” “Validate Test Procedures by Inspection and Traces to Requirements” “Validate Test Design by Inspecting Traces from Scenarios”	The STP provides the detailed test steps necessary for test verification. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.

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Artifact Name	Need/Applicable Analysis	Use/Comments
Software Test Case	<p>“Validate Test Cases by Inspection and Traces to Requirements”</p> <p>“Validate Test Plan by Inspection”</p> <p>“Validate Test Procedures by Inspection and Traces to Requirements”</p> <p>Validate Test Design by Inspecting Traces from Scenarios”</p>	<p>The Software Test Cases (and the MPCV STD which reproduces much of the same information via the incorporated Test Information Sheets) provide:</p> <p>requirements to be addressed in each test case</p> <p>verification criteria for each test</p> <p>identification if the test is partial or full verification of the requirement and the description of any partial verifications</p> <p>high level of the test activities</p> <p>test configuration information</p> <p>The STD provides more complete information. The Test Case provides the information chronologically earlier.</p> <p>These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>
<redacted>	<p>“Verify Test Execution by Inspection of Test Cases, Inputs and Results”</p> <p>Validate Test Design by Inspecting Traces from Scenarios”.</p>	<p>The <redacted> provides the verification method for each requirement.</p> <p>These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>

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Artifact Name	Need/Applicable Analysis	Use/Comments
Software Build Plan Matrix	<p>“Verify Software Design by Inspecting Traces to Requirements and Software Architecture”</p> <p>“Verify Software Interface Design by Inspection Against Interface Requirements”</p> <p>“Verify Software Implementation by Inspecting Traces to Requirements”</p> <p>“Verify Software Code Quality using Static Analysis Tools”</p> <p>“Validate Test Cases by Inspection and Traces to Requirements”</p> <p>“Validate Test Plan by Inspection”</p>	<p>Phased FSW development and phased testing requires a controlled source of build planning that defines the content of each build. These analyses may be performed for MPCV Program or HEO-ESD Integration purposes.</p>
Change Requests / Implementations and updated artifacts	<p>“Validate Requirements by Inspecting Against Quality Criteria and System/Software Background Artifacts”</p>	<p>Tracking known changes and additions will increase the efficiency in which issues are addressed and allow IV&V to perform analysis with the most up-to-date information. This will affect the performance of all TF elements.</p>
<redacted>	<p>“Verify Software Interface Design by Inspection Against Interface Requirements”</p> <p>“Verify Software Implementation by Inspecting Traces to Requirements”</p> <p>“Validate Test Procedures by Inspection and Traces to Requirements”</p>	<p>The <redacted> provides supplemental reference information necessary for test V&V, design V&V and implementation V&V.</p>
System and Software Architecture Documents	<p>“Validate Software Architecture by Inspecting Traces to Essential Properties”</p> <p>“Validate Key Driving Requirement by Tracing to System Architecture and Stakeholder Expectations”</p>	<p>This analysis may be performed for MPCV Program or HEO-ESD Integration purposes.</p>

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Artifact Name	Need/Applicable Analysis	Use/Comments
System Security Plan, Software Security requirements, Program Protection Plans (PPP), Threat Assessment, and other sources of system descriptions to include System's Federal Information Processing Standard (FIPS) - 199 Classification, System's FIPS-200, major components, classes of data, data sources, destinations, communications, or Security ConOps	“Validate System Security Categorization and Regulatory Security Requirements by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 1)” “Verify Security Control Selection and Threats/Risks Identification by Inspection using Security Risk Management Framework (NIST-SP-800-37, Step 2)”	This analysis may be performed for MPCV Program or HEO-ESD Integration purposes.
Software Interface Design	“Verify SW Interface Implementation by Inspection Against Interface Design”	This analysis may be performed for MPCV Program or HEO-ESD Integration purposes.

2.3 IV&V Focus

As part of Software Assurance, IV&V plays an important role in the overall software risk mitigation strategy applied throughout the entire software lifecycle to improve the safety and quality of software systems. To understand the risk profile, the IV&V team performs assessments of software risks on Mission Projects or Programs. These assessments meet two objectives:

1. Create a portfolio to support prioritization of technical scope across all IV&V Projects, and
2. Create a mission-specific view to support planning and scoping of IV&V Project work on each individual IV&V Project.

The IV&V Team uses a two-phase process to support both of these objectives. Phase-One, known as Portfolio Based Risk Assessment (PBRA), supports objective 1 while Phase-Two, known as Risk Based Assessment (RBA), supports objective 2.

For Phase-One, the IV&V Team utilizes the PBRA process as the means to prioritize and optimize IV&V resources. The PBRA process assesses the top-level capabilities of the system, for which software contributes, in terms of impact of a limitation (defect) and likelihood of a limitation. The result of this assessment is an overall rating for each capability that is mapped against a 5x5 risk matrix used to prioritize the IV&V efforts across the NASA IV&V Program as well as within a particular IV&V Project.

For Phase-Two, the RBA process is used for planning and scoping the IV&V Project. The updated entity-to-capability mapping produced by this phase provides a view of the system that serves as a useful tool for discussing and deciding where to apply IV&V effort.

The IV&V Team will share PBRA/RBA results/assessment ratings with Program and Agency stakeholders. Input and feedback on this data from the Program is encouraged. The IV&V Team will revisit the PBRA/RBA results and assessment ratings for the Program every six months (or more frequently, if warranted), and any changes to this data will be communicated to the Program. PBRA results for these IV&V efforts are contained in Appendix A. RBA results for these efforts are contained in Appendix B. For additional information on the PBRA/RBA process, see [S3106, PBRA and RBA Process](#).

3 Roles, Responsibilities and Interfaces

To facilitate successful execution of the IV&V efforts as described in this plan, various roles, responsibilities, and interfaces are maintained. These roles and responsibilities can be described in terms of personnel within the NASA IV&V Program and personnel within the Program. The subsections below describe these roles and responsibilities. Figure 3-1 depicts the interfaces associated with these roles.

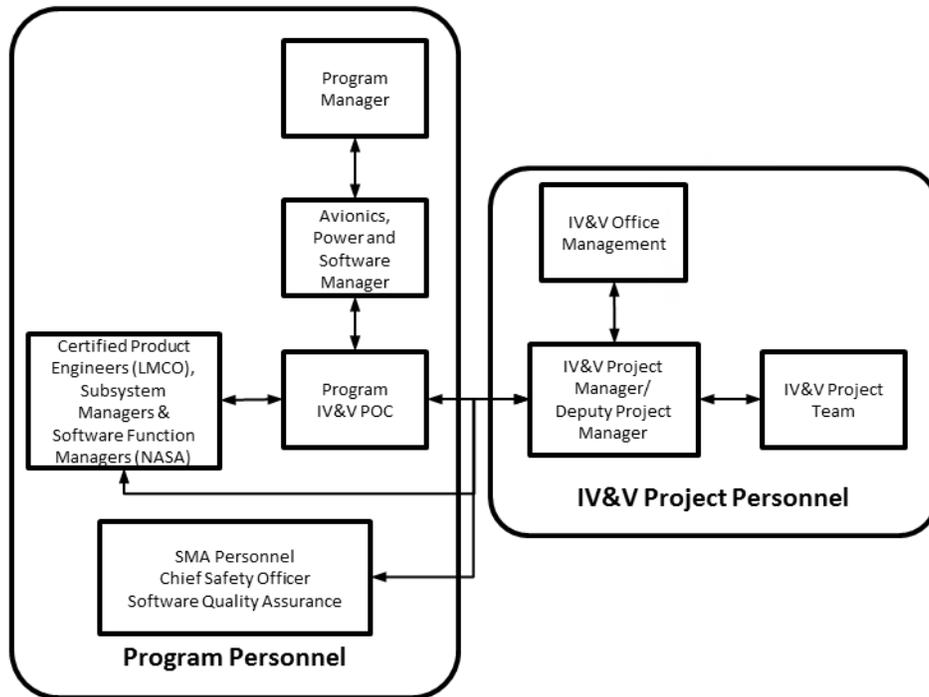


Figure 3-1 – IV&V Team and Program Interfaces

3.1 IV&V Program

3.1.1 Research Support

The NASA IV&V Program conducts research in various areas that directly contribute to the effectiveness of IV&V. NASA IV&V researchers require actual Program data to accomplish realistic research. All Program data will be closely protected and not released outside the NASA IV&V Program and its research contractors. No proprietary or export-controlled Program data will be used to support NASA IV&V research unless there is a non-disclosure agreement in place between the NASA IV&V researchers and the owner of the proprietary data. Any such authorized use of Program data will be in compliance with all United States export control laws and regulations. The Program agrees that non-proprietary, non-export-controlled, non-Sensitive But Unclassified (SBU) Program data may be used to support software IV&V-related research. The NASA IV&V Program agrees that any related research will not affect Program or subcontractor personnel or resources. The NASA IV&V Program agrees not to publish or allow publication of any research document that can be referenced back to the Program without specific, prior written approval of the Program’s IV&V POC.

3.1.2 IV&V Metrics Support

The NASA IV&V Program strives to ascertain the value and effectiveness of the IV&V efforts. Some of these efforts require the comparison of software issues (discrepancies) identified by IV&V and software issues identified by the Program, as well as ascertaining post-launch software anomalies. The Program, subject to the IV&V Point of Contact's discretion, will provide access to the data, or the actual data necessary to support these efforts. The IV&V PM will work with the IV&V Point of Contact to identify the specific data of interest, but it is expected that this data will be of the following nature:

- (a) Software issues: description of the software issues identified by the developers, including issue type, phase introduced, phase found, relevant Computer Software Configuration Item (CSCI), severity of issue, and efforts to fix if available and
- (b) Post-launch software anomalies: description of the software issue, overall impact, relevant CSCI, root cause/contributing cause, associated fix/resolution to the defect/anomaly.

Access to the data can be in the form of access to Program/developer problem reporting systems, post-launch anomaly tracking systems or via periodic reports delivered to the IV&V PM. Any access to existing systems would be on a non-interfering basis to minimize impact to the Program.

3.2 IV&V Team

Primarily, the IV&V Team consists of an IV&V PM and an analyst group. Because of the size of the MPCV IV&V Team and the importance of the associated work, the MPCV IV&V Team may also include a Deputy PM (DPM). For the purposes of the IPEP, all actions assigned to the PM may be performed by the PM or DPM.

The IV&V PM serves as the primary interface with the Program in support of the IV&V efforts. The IV&V PM is responsible for the overall leadership and direction of the IV&V efforts. The IV&V PM is responsible for establishing the goals and objectives of the IV&V efforts, performing the PBRA and subsequent RBAs, performing project management, tracking and oversight, and conducting risk management of the IV&V efforts. The IV&V PM is responsible for ensuring that the commitments with the Program as defined in this plan are met.

In addition, the IV&V Team is supported by IV&V analysts that perform verification and validation related analysis. At times and at the request/direction of the IV&V PM, the IV&V analyst(s) may interface with the Program.

3.3 Program Personnel

The Program will provide an IV&V Point of Contact for formal interactions between the IV&V Team and the Program. The Program IV&V Point of Contact will facilitate the IV&V tasks to be performed through coordination between Program personnel, the NASA Subsystem Managers (SSMs), NASA Software Function Managers (SFM), the developer's Certified Product Engineers (CPEs), and the IV&V PM. The Program's IV&V Point of Contact will be informed of all direct communications with Lockheed personnel.

The IV&V PM may contact the Program's Safety and Mission Assurance (SMA) personnel directly without coordinating with the Program IV&V Point of Contact; however, the IV&V PM should keep the Program's IV&V Point of Contact aware of IV&V interactions with the Program's SMA personnel. S&MA personnel reporting to the SM&A Manager and Chief Safety Officer should be made aware of discussions between IV&V and the MPCV Program.

The Program will provide the IV&V Team the necessary interfaces, Program development data/documentation, and any other negotiated resources to perform the IV&V tasks. The Program will provide such data/documentation to IV&V at the same time as the information is made available to the Program's teams. The Program will provide draft and final versions of IV&V-requested development artifacts. It is expected that many of the development artifacts necessary to perform the IV&V analysis will be formal deliverables. However, in some cases non-deliverable or informal documentation (e.g., Software Development Folders, incremental pre-release builds, etc.) may be needed to support the IV&V analysis. In such cases, the Program IV&V Point of Contact will make these items available on a case-by-case basis after taking into consideration various factors, including but not limited to, overall impact on the Program. The incremental pre-release builds, in particular, are often necessary for the IV&V Team to achieve in-phase identification of issues. While not required, electronic access to Program data/artifacts is preferred (e.g., requirement tracing tools and databases, issue tracking systems, document repositories, etc.).

The Program, through the IV&V Point of Contact, is responsible for working with the IV&V Team to resolve issues/risks identified by the IV&V Team.

The Program, through the IV&V Point of Contact, will support the research and metrics support related initiatives as described above.

For these IV&V efforts, applicable contact information is identified in Tables 3-1 and 3-2 below.

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Table 3-1 – IV&V Team Contact Information

NASA IV&V Program		
Position	Name	Contact Information
<redacted>	<redacted>	<redacted>

Table 3-2 – Program Contact Information

Program		
Position/Role	Name	Contact Information
<redacted>	<redacted>	<redacted>

4 IV&V Products and Communication/Reporting Methods

The IV&V Team generates various products and utilizes various communication/reporting methods throughout the lifecycle. The subsections below describe the IV&V products and associated communication/reporting methods further.

4.1 IV&V Products

4.1.1 Analysis Reports

Over the course of the lifecycle, the IV&V Team may generate analysis reports that document the results of the analyses performed. These reports will typically describe what the IV&V Team analyzed (Program artifacts), a high-level description of the process/approach and tools used (if applicable), and associated results. The IV&V Team will forward the analysis reports to the Program as defined in Table 4-1. In addition to these reports the IV&V Team will provide IV&V analysis results in phase with the Program’s activities. The analysis reports will not delay delivering the issues to the Program but are more of a collection of the issues already formally delivered to the Program (Reference section 4.1.3).

Table 4-1: IV&V Analysis Reports

Product Name	Recipient
Software Requirements Analysis Reports	IV&V Point of Contact ¹
Software Design Analysis Reports	IV&V Point of Contact ¹
Software Build Analysis Reports	IV&V Point of Contact ¹
Software Test Analysis Reports	IV&V Point of Contact ¹
MPCV System Milestone reports	IV&V Point of Contact ¹
MPCV FSW Milestone reports	IV&V Point of Contact ¹

4.1.2 Lifecycle Review Presentations

Throughout the lifecycle, the IV&V Team supports formal Program lifecycle/milestone reviews (e.g., the Preliminary Design Review [PDR], etc.) by providing information that portrays the status of IV&V efforts, including overall goodness of product data, at the time of the review. At a minimum, and as required by the NASA Agency’s Chief SMA Officer, the IV&V Team will present status of the IV&V efforts and associated recommendations at the pre-launch MPCV Safety and Mission Success Review (SMSR)

4.1.3 Reviews and Working Groups Support

¹ Analyses associated with HEO-ESD Integration will also be provided to appropriate Points of Contact for other Programs (e.g., SLS or GSDO) or for HEO-ESD integration activities or offices.

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IV&V will support mutually agreed Program working groups or reviews, and provide appropriate analysis results through those forums. This will provide IV&V analysis results in phase with the Program's activities and submitted in the Program's own formats when possible. The material submitted through such forums will also be communicated via either "Issues" (reference Section 4.1.4) or "Analysis Reports" (reference Section 4.1.1). "Analysis Reports" or "Issues" will include a reference to the original submission.

Reviews and Working Group Support Resolution Path: the Program's own review disposition processes will be applied to submitted materials. Applicable dispositions include: (a) the submission is rejected/withdrawn (tracked as a closed IV&V issue for IV&V metrics), (b) the submission is considered legitimate, accepted by the Program and turned into an IV&V issue, or (c) the submission is considered legitimate but rejected for programmatic reasons and is turned into a risk. Matters requiring elevation above the working group or review process will apply the "Issue Resolution Path" detailed below.

4.1.4 Issues

An issue is a type of output from an IV&V analysis task. An issue represents a limitation identified within a development artifact that is formally communicated to the Program. Issue(s) have a documented impact and are assigned a severity rating between 1 (highest severity) and 5 (lowest severity) as defined in Table 4-2 below. Issues of severity rating 1-3 require a formal disposition/response by the Program and must be verified to have been addressed prior to closure. Issues of severity rating 4 or 5 may be reviewed by the Program, but may not receive a formal response/resolution. Resolving severity rating 4 and 5 issues, nonetheless, will certainly improve the quality of the Program's software and reduce or eliminate risks associated with maintenance of the software product.

Issue Resolution Path: The Program will review the issue data as provided by the IV&V Team. If the Program concurs that the issue is legitimate, the Program will propose a solution. When the Program identifies that they plan to fix the issue, the issue will be put in a "To Be Verified" state. Subsequent to the proposed solution being made, the Program will notify the IV&V Team that the corrective action has been made and will provide the appropriate evidence (e.g., updated development artifacts, etc.) to the IV&V Team for verification and subsequent closure of the issue. If verification of the corrective action cannot be completed, the IV&V Team will request additional feedback/data from the Program.

If there is a dispute at any time in the issue resolution process, the issue may be placed in an "In Dispute" state, at which time the Program and IV&V Team can continue dialog on the issue. Subsequent to these discussions, the issue may be withdrawn, placed in the "Project (Program) Accepts Risk" state, or it may be reverted to the "To Be Verified" state.

If the Program does not concur that the limitation described in the issue is legitimate, the Program will provide appropriate data and/or explanation to support this conclusion. The IV&V Team will review and consider this data and if the IV&V Team is in agreement, the issue will be withdrawn. If the IV&V Team is not in agreement, additional dialog and discussion between the Program and IV&V Team may be required and an appropriate course of action will be determined.

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Table 4-2: Issue Severity Rating and Description

(Source: [S3105, Guidelines for Writing IV&V TIMs](#))

Severity	Capability Affected	Success Criteria	Safety	Test	Cost & Schedule	Other
1 Catastrophic	Loss of an essential capability OR Complete loss of mission critical asset	Inability to achieve minimum mission success criteria	Causes loss of life or injury	N/A	N/A	N/A
2 Critical	Degradation of an essential capability OR Damage/destruction to mission asset which affects performance	Impact to the accomplishment of a mission objective	N/A	Essential capability not tested	Significant cost increases or schedule slip	Significant reduction to requirements margins or design margins
3 Moderate	Degradation of system dependability OR Loss of a non-essential capability	Impact to the accomplishment of extended/ optional mission objectives	N/A	Essential capability inadequately tested	Cost or schedule impact resulting from redesign, reimplementation, and/or retest	Degradation of an essential capability or inability to accomplish mission objective, but with a known workaround
4 Minor	Degradation of a non-essential capability	N/A	N/A	Non-essential capability inadequately tested	Defect impacting maintainability on current mission or reuse on future missions	Creates inconvenience for operators, crew or other projects' personnel
5 Communications Or Editorial	Defect impacting documentation and communication clarity					

4.1.5 Risks

By conducting IV&V analysis, simple routine awareness, and/or interactions over the course of the lifecycle, the IV&V Team may become aware of circumstances or data points that represent a potential undesirable event for the Program. The IV&V Team will document such items as risks and will formally communicate these risks to the Program with appropriate data and/or explanation to support these risks. The IV&V Team will assess all risks based on the likelihood and consequence of the undesired event using the Program’s likelihood and consequence ranking criteria (as defined in the Program’s risk management plan). The IV&V Team may also provide recommendations to eliminate, reduce, or mitigate the risks. The IV&V Team will coordinate all risks with the Program prior to formal submission. To facilitate the submission of risks, the IV&V Team may request access to the Program’s Risk Management System (RMS) or repository, and the IV&V Team and IV&V Point of Contact will work together to determine the appropriate level of access (e.g., read-only, write, none) to the RMS/repository.

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The Program's risk management plan can be found in <redacted>.

Typically, Projects and Programs retain residual risks throughout the lifecycle. As such, the IV&V Team may choose to assess the Program's residual risks. At minimum, and as required by the Chief SMA Officer, the IV&V Team will evaluate residual risk data as provided by the Program in preparation for the MPCV Safety and Engineering Review Panel (SERP). The IV&V Team will communicate their stance with regards to such residual risk data to the Program prior to the SERP.

Risk Resolution Path: The Program will review risks as provided by the IV&V PM. If the Program agrees with the nature of the risk they may choose to take ownership of the risk. Subsequently, the Program will document/capture the risk and associated mitigation plan(s) in the Program's RMS. It is expected that the Program actively manages, tracks, and mitigates such risk. The IV&V Team will monitor the progress or lack thereof of these activities until the risk is closed. This monitoring may be performed independently or via the Program providing status data to the IV&V Team. If the IV&V Team determines that the risk is not being actively managed, the IV&V Team will discuss this with the Program IV&V Point of Contact and determine an appropriate course of action.

If the Program decides not to accept, mitigate and manage a risk, the Program will provide appropriate data and/or explanation to support this conclusion. The IV&V Team will review/consider this data and if the IV&V Team is in agreement, they will withdraw the risk. If the IV&V Team is not in agreement, additional dialog/discussion between the Program and IV&V Team may be required and an appropriate course of action will be determined.

4.1.6 Item Tracking/Monitoring and Escalation

All data such as issues and risks are recorded and provided to the Program as they are identified and/or as per an agreed-to schedule. The IV&V Team will evaluate the Program's feedback/response to this data and update the status of this data in terms of tracking towards closure/resolution in the appropriate data repository at the NASA IV&V Facility. In addition, this "goodness of product" data will be documented in other IV&V products including but not limited to lifecycle review presentations, analysis reports and recurring/ad hoc status reports as applicable.

Given the reporting data mentioned above, any areas of disagreement regarding this data that cannot be resolved between the IV&V Team and the Program within an appropriate period, the IV&V PM will elevate the issue to IV&V Office Management. The IV&V PM will ensure that the Program is aware that the issue is being elevated, and the Program will elevate the issue to their management. The final level of resolution will be the MPCV Program Control Board (MPCB).

4.2 IV&V Communication and Reporting Methods

Communications and reporting methods between the IV&V Team and the Program occur in both formal and informal fashion. Formal communication and reporting methods include delivery/receipt of IV&V analysis reports and associated technical data, IV&V briefings at

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lifecycle reviews and associated forums, and dialog between the IV&V Team and Program regarding scope, priorities, access to resources, etc. consistent with the data in this plan. Informal communications and reporting methods include recurring teleconferences and tag-ups between the IV&V Team and Program IVV Point of Contact, requests for and provision of development artifacts, technical discussion on IV&V analysis results, and dialog/exchange of relevant data to facilitate resolution of IV&V issues and risks.

4.2.1 Lifecycle Review Presentations

The IV&V PM will provide IV&V status data and associated results/conclusions of the IV&V efforts at various Program lifecycle/milestone reviews as defined in Table 4-3 below. The IV&V Team will communicate and coordinate the overall message/content of the presentation with the Program prior to the actual review.

Table 4-3: Milestone Review IV&V Presentations

Milestone Review	Program Recipient	Input Due
CSCI PDRs, CDRs, DDRs for CSCIs being assessed	IV&V Point of Contact	14 Calendar days prior to review ²
Mission Reviews (e.g., PDR, CDR, MRR, LRR, SMSR)	IV&V Point of Contact	14 Calendar days prior to review ²

4.2.2 Agency/Mission Directorate/Center Management Briefings

Throughout the course of the lifecycle, the IV&V Team is required and/or requested to present IV&V status to various stakeholders including but not limited to Center Management, Mission Directorates, etc. The IV&V Team will communicate and coordinate the overall message/content of these presentations with the Program prior to the actual review as defined in Table 4-4 below.

Table 4-4: Additional Reporting Events

Milestone Review	Program Recipient	Input Due
IV&V Board of Advisors (IBA) Semi-Annual Briefings	IV&V Point of Contact	5 Calendar days prior to review
Monthly GSFC Status Reporting	IV&V Point of Contact	5 Calendar days prior to review

4.2.3 Routine Tag-ups

The IV&V Team will work with Program personnel to establish routine tag-ups to discuss overall IV&V status, development artifacts needs/requests, results of IV&V analyses (issues and risks), status of Program schedule and artifacts, resolution of IV&V issues and risks, and

² The delivery of IV&V input may be affected by Program artifact availability.

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delivery of formal IV&V reports, etc. Such tag-ups may occur on a weekly, bi-weekly, or monthly basis as agreed to by both parties. These routine tag-ups represent the preferred method for communicating and resolving any issues and/or risks that the IV&V Team has identified.

4.2.4 Technical Authorities

The IV&V Team will work with independent Technical Authorities (TAs), e.g., Chief, Safety and Mission Assurance (CSMA), Chief Health and Medical Officer (CHMO), NASA Chief Engineer (CE), to assure communication of risks, issues, or other concerns when the MPCV Program and the IV&V team are unable to resolve the concern or when the concern should be given extra visibility. The TAs will be provided full access to IV&V project records directly and will be allowed to independently assess the project records.

Appendix A: IV&V PBRA Results

Figure A-1 below depicts the PBRA results for the EM-1/2 missions. The IV&V PBRA process is found in S3106 “PBRA and RBA Process”. Figure A-2 identifies the HEO-ESD Capabilities allocated to MPCV Entities. The supporting data / rationale for this data is maintained by the IV&V PM and is available upon request. Capabilities that fall into the green category will not receive IV&V. Capabilities in the red category will typically receive IV&V, as these represent the most critical capabilities of the system. Capabilities that are in the yellow category may receive IV&V pending funding availability and other factors.

Figure A-1 HEO-ESD PBRA Results

<Figure redacted>

Figure A-2 HEO-ESD Capabilities allocated to MPCV Entities

<Figure redacted>

Figure A-3 (below) depicts the HEO-ESD capabilities allocated to the MPCV Program entities as analyzed to establish IV&V’s focus areas. HEO ESD capabilities in dark pink colored rows are capabilities within IV&V’s focus and were identified by the NASA “Joint Program/Exploration Systems Development Integrated Mission Analysis (IMA) Report”, ESD 10014. MPCV entities in dark blue columns are the CSCI entities within IV&V’s focus. Complete discussion of the PBRA results within Figure A-3 may be found in complete EM-1/2 PBRA in < redacted>

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Figure A-3 HEO-ESD Capabilities allocated to MPCV Entities

Figure A-3 depicts the HEO-ESD capabilities allocated to the MPCV Program entities.

<Figure redacted>

Appendix B: IV&V RBA Results

Figure B-1 below depicts the RBA results for the EM-1/2 missions. The IV&V RBA process is found in S3106 “PBRA and RBA Process”. The supporting data / rationale for this data is maintained by the IV&V PM and is available upon request. Capabilities that fall into the green category will not receive IV&V. Capabilities in the red category will typically receive IV&V, as these represent the most critical capabilities of the system. Capabilities that are in the yellow category may receive IV&V pending funding availability and other factors.

Figure B-1 EM-1/2 RBA Results for Multi-Purpose Crew Vehicle

..
<Figures redacted>

The complete EM-1/2 RBA can be found in < redacted>

Appendix C: IV&V Heritage Review & Applicable Lessons Learned

The complete MPCV *Heritage Review document*, including applicable *Lessons Learned*, is located < redacted >

The purpose of the heritage review is to survey prior IV&V projects for applicability of their results to the Program and to document references to applicable project results for use in MPCV IV&V work. The MPCV design is a continuation of the Constellation Orion project’s design. This is an extremely detailed and applicable “heritage” when compared to typical IV&V projects.

A heritage project summary table is one aspect of the MPCV Heritage Review report. This table is also shown below:

Table C-1: Heritage Project Summary

<Table redacted>

The MPCV design is a continuation of the design initiated under the earlier, now cancelled, Constellation Program (CxP). MPCV software has direct and indirect lineage to the software that was under development at the time that the CxP Program was cancelled. The software design for the EM-1/2 flights was evolved from the successful EFT-1 test flight software to be compliant with NASA human rated flight software development standards and practices. Table C-2 presents changes in FSW at the CSCI level between CxP Orion, MPCV EFT-1, and EM-1/2 missions.

Table C-2: MPCV Software Heritage From CxP “Orion”

<Table redacted>

Appendix D: Technical Scope

The MPCV Technical Scope & Rigor (TS&R) document outlines where IV&V's effort will be applied on the MPCV IV&V project for the FY16 and the approaches considered for performing technical tasks. The MPCV TS&R for EM-1 is located < redacted >

The focus of the EM-1 MPCV IV&V effort is being driven by the IV&V assurance objectives for EM-1, defined at the HEO-ESD level, as follows:

The HEO-ESD IV&V efforts shall assure that the software of selected safety-critical and mission-critical HEO-ESD capabilities of the GSDO, MPCV and SLS Programs required to support the EM-1 mission will operate reliably and safely. The HEO-ESD IV&V efforts shall assure that the software of selected safety-critical and mission-critical HEO-ESD capabilities of the GSDO, MPCV and SLS Programs required to support the EM-1 mission will operate reliably and safely in an integrated fashion. These efforts shall be performed with the following caveats:

- Efforts applied under nominal conditions
- Efforts applied under selected off-nominal conditions
- Integration, including interfaces, analysis efforts are between ESD programs (SLS, GSDO and MPCV) up to the interface with Range Safety Officer (RSO), Mission Operations and Space Communications and Navigation (SCaN)
- 'Selected' HEO-ESD capabilities is defined by the HEO-ESD PBRA assessment, as presented in Appendix A, and as modified by allocated resources
- Safety critical and Mission critical are defined by NPR 7150.2B & NASA-STD-8719.13(C)
- EM-1 mission objectives as defined by the HEO-ESD Concept of Operations (ESD-10012) and Integrated Mission Analysis (IMA) report (ESD 10014).

The assurance objective establishes the basis for the following assurance objective for EM-1, defined at the MPCV Program level:

The MPCV IV&V efforts shall assure that the selected safety-critical and mission-critical MPCV software required to support the EM-1 mission will operate reliably and safely. These efforts shall be performed with the following caveats:

- Efforts applied under nominal conditions
- Efforts applied under selected off-nominal conditions
- 'Selected' is defined by the MPCV RBA assessment, as presented in Appendix B, and as modified by allocated resources
- Safety critical and Mission critical are defined by 7150.2 & 8719.13(C)
- EM-1 mission objectives as defined by the HEO-ESD Con-ops and IMA as allocated to MPCV

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For FY16, based on the HEO-ESD PBRA, the MPCV RBA and availability of resources, the focus for the MPCV IV&V effort will be limited to the following MPCV RBA entities (MPCV CSCIs):

- < redacted >

The following CSCIs are not provided IV&V coverage during FY16. These CSCIs were not selected for coverage primarily due to a lack of a direct driving relationship between the CSCIs and the selected HEO mission capabilities, or perceived lower risks in the CSCIs' development due to comparatively lower complexity with respect to covered CSCIs.

< redacted >

Appendix E: Reference Documentation

Table E-1: Relevant Documentation

Document	Title	Link or Date
IVV 09-1	Independent Verification and Validation Technical Framework	IVV 09-1
S3105	Guidelines for Writing IV&V TIMs	S3105
S3106	PBRA and RBA Process	S3106
NASA-STD-8719.13C	NASA Software Safety Standard	NASA-STD-8719.13C
NPR 7150.2	NASA Software Engineering Requirements	NPR 7150.2
NPR 8715.3C	NASA General Safety Program Requirements	NPR 8715.3C

For more information regarding the Multi-Purpose Crew Vehicle Program, see the Program's website at: <http://www.nasa.gov/exploration/systems/mpcv/index.html>.

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Appendix F: Acronyms

APEX	Application Executive
< redacted >	
< redacted >	
CD	Capability Development
CDH	Command and Data Handling
CDR	Critical Design Review
CE	NASA Chief Engineer
CEV	Crew Exploration Vehicle
CFSW	Common FSW
CHMO	Chief Health and Medical Officer
CM	Configuration Management
CMT	Communications and Tracking
COTS	Commercial Off the Shelf
CPE	Certified Product Engineer
CRC	Cyclic Redundancy Check
CSCI	Computer Software Configuration Item
CSMA	Chief, Safety and Mission Assurance
CSO	Chief Safety Officer
CxP	Constellation Program
< redacted >	
DDR	Detailed Design Review
< redacted >	
DIIR	Development Integration Issue Record
DIRD	Design Implementation Requirements Documents
DOORS	Dynamic Object Oriented Requirements System
DPM	Deputy PM
DRM	Design Reference Mission
< redacted >	
ECM	Enterprise Content Manager
EDL	Entry, Descent, and Landing
EFT-1	Exploration Flight Test number 1
EM-1	Exploration Mission 1
EM-2	Exploration Mission 2
< redacted >	
FCM	Flight Control Module
FMEA	Failure Modes & Effects Analysis
FMECA	Failure Mode Effects and Critical Analysis
FS	File System CSCI
FSPT	Flight Software Product Team

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FSW	Flight Software
FT	Fault Tolerant
FTA	Fault Tree Analysis
GNC, GN&C	Guidance Navigation and Control
GSDO	Ground Systems Development and Operations
HA	Hazard Analysis
HEO	Human Exploration and Operations
HEO-ESD	Human Exploration and Operations – Exploration Systems Development
IAGTAS	IV&V Analysis Guideline and Template for ARINC-653 Systems
IBA	IV&V Board of Advisors
ICD	Interface Control Document
IPEP	IV&V Project Execution Plan
IRD	Interface Requirements Document
IV&V	Independent Verification and Validation
JSTAR	Jon McBride Software Testing and Research Laboratory
LAS	Launch Abort System
LEO	Low Earth Orbit
LM	Lockheed Martin
LOM	Loss of Mission
LRR	Launch Readiness Review
MPCB	MPCV Program Control Board
MPCV	Multi-Purpose Crew Vehicle
MRR	Mission Readiness Review
MSR	Monthly Status Review
MVP	Master Verification Plan
NGO	Needs Goals and Objectives
NODIS	NASA Online Directives Information
NPR	NASA Procedural Requirements
< redacted >	
< redacted >	
< redacted >	
ORBIT	Observation Risk Backlog Issue Tracking System
OSMA	Office of Safety and Mission Assurance
< redacted >	
PBRA	Portfolio Based Risk Assessment
PDR	Preliminary Design Review
PDU	Power and Data Unit
PHA	Preliminary Hazard Analysis
PLOC	Probability of Loss of Crew
PLOM	Probability of Loss of Mission
PM	Project Manager
POC	Point of Contact
PTR	Preliminary Technical Review
RBA	Risk Based Assessment
RCS	Reaction Control System

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RMS	Risk Management System
< redacted>	
RSO	Range Safety Officer
RTOS	Real-Time Operating System
SBU	Sensitive But Unclassified
SCaN	Space Communications and Navigation
SDD	Software Design Document
SDP	Software Development Plan
SEIT	Systems Engineering Integration Team
SERP	Safety and Engineering Review Panel
SFM	Software Functional Manager
SLS	Space Launch System
SLP	System Level Procedure
SM	Service Module
SMA	Safety and Mission Assurance
SMC	Service Module Control
SME	Subject Matter Expert
SMG	Systems Management CSCI
SMSR	Safety and Mission Success Review
< redacted>	
SR	Software Request
SRS	Software Requirements Specification
SQA	Software Quality Assurance
SSM	Subsystem Manager
STD	Software Test Description
STOR	Storage
STP	Software Test Procedure
STR	Software Test Report
SW	Software
TA	Technical Authority
TBR	To Be Refined
TF	Technical Framework
TIM	Technical Interchange Meeting
TQ&E	Technical Quality and Excellence
TS&R	Technical Scope & Rigor
< redacted>	
T&V	Test and Verification
< redacted>	
< redacted>	
< redacted>	
VID	Video
< redacted>	
< redacted>	
< redacted>	
V&V	Verification and Validation

Appendix G: Fiscal Year 16 IV&V Efforts

G.1 FY 16 Goals/Objectives

Fiscal Year 2016 MPCV IV&V project goals are intended to support future missions EM-1(uncrewed); AA-2 (uncrewed); EM-2 (crewed); EM-3(crewed).³

EM-1: EM-1 is scheduled for launch in September of 2018. The EM-1 mission is an uncrewed flight to a deep retrograde orbit several thousand miles beyond the moon's orbit. EM-1 is the first MPCV mission launched on the SLS.

Prior to EM-1 launch:

- The ~45% of MPCV FSW delivered for EFT-1 will need to complete additional verification activities (primarily requirements, test documentation and implementation phase activities (TBR)) to retire risks associated with the development of EFT-1 FSW under EFT-1's lesser standards of rigor, and
- The ~25% of MPCV FSW uniquely associated with EM-1 and later flights will also need to complete development, verification and validation.

The primary IV&V EM-1 goals/objectives for FY16 are:

- Work with the MPCV Program IV&V POC and representatives to identify, communicate and resolve risks, focusing on factors that are likely to impact IV&V and Program objectives in areas of performance, safety, schedule and cost.
- Work with the MPCV IV&V POC and representatives to identify, communicate, disposition and resolve technical issues in a timely and consistent manner, as a result of IV&V analyses performed throughout the fiscal year.
- Support management and technical reviews by assessing the review materials, attending the reviews, providing requested status and/or data to the Program, presenting at the reviews, and providing task reports and anomaly reports.
- Assess and provide V&V assurance for system, subsystem and in focus FSW (as identified in Appendix D) Concept & Architecture through analysis (TF2) in order to validate the selected solution and ensure that no false assumptions have been incorporated in the solution, and document the results via an addendum report to the baseline summary report.
- Assess and provide V&V assurance for system, subsystem and in focus FSW (as identified in Appendix D) requirements through validation analysis (TF3) in order to ensure that the requirements are high quality and will adequately meet the needs of the system, considering the operational environment under nominal and selected off-nominal conditions and that no unintended features are introduced, and document the results via an addendum report to the Requirements baseline report.

³ The EFT-1 test flight was successfully flown on December 5, 2014. All analyses associated with the EFT-1 work are complete. References to EFT-1 analyses have been deleted from the 2016 revision of this IPEP unless the content is vital to discussion of EM-1 project planning.

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- Assess and provide V&V assurance for in focus FSW (as identified in Appendix D) Design (TF5) and Implementation (TF6) software and documentation through analysis for FSW Release 24 (ref. release dates in Table G-1) Release 25 and Release 26. Document the results of Release 24 and 25 analyses via an associated build reports. For software design analysis, this involves assuring that the design is a correct, accurate and complete transformation of the software requirements, meets the operational need under nominal and selected off-nominal conditions, and introduces no unintended features. For software implementation analysis, this involves assuring that the source code correctly implements the requirements, meets the operational need under nominal and selected off-nominal conditions, and introduces no unintended features.
- Assess and provide test (TF 4.0) V&V assurance for in focus FSW (as identified in Appendix D) Test (TF4) documentation through analysis for FSW Release 24, Release 25, and Release 26. Document the results of Release 24 and 25 analyses via associated build reports. This involves assuring that the test related content will serve as a sufficient means to verify and validate that the implementation meets the requirements and operational need under nominal and selected off-nominal conditions.
- Assess and provide V&V assurance for software and information security as represented in architecture (TF2.6) and in-focus FSW requirements, design, code, and test software and documentation assuring preservation of the availability, integrity, and confidentiality for safety critical & mission critical capabilities.

EM-2: EM-2 is scheduled for launch in December of 2020. EM-2 is a crewed lunar orbital mission launched on the SLS. Prior to EM-2 launch the 28% of MPCV FSW uniquely associated with EM-2 and later flights must complete development, verification and validation. EM-2 FSW development started in FY15 as a parallel path of releases to EM-1 and consisted of concept of operations, architecture development, crew interface development (e.g., Rapid Prototyping Lab displays development), risk reduction activities, or other pre-PDR/pre Key Decision Point 1 FSW development activities. This work is scheduled to be completed in FY16. The main line of the EM-2 FSW is scheduled to begin in FY16. No releases of the mainline EM-2 FSW (Build 70 series) are scheduled for delivery in FY16. The primary EM-2 activities for FY16 are:

- Work with the MPCV Program IV&V POC and representatives to identify, communicate and resolve risks, focusing on factors that are likely to impact IV&V and Program objectives in areas of performance, safety, schedule and cost.
- Work with the MPCV IV&V POC and representatives to identify, communicate, disposition and resolve technical issues in a timely and consistent manner, as a result of IV&V analyses performed throughout the fiscal year.
- Support management and technical reviews by assessing the review materials, attending the reviews, providing requested status and/or data to the Program, presenting at the reviews, and providing task reports and anomaly reports.
- Assess and provide V&V assurance for system, subsystem and in focus EM-2 FSW (as identified in Appendix D) Concept & Architecture through analysis (TF2) and document the results via an associated EM-2 summary report.

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- Assess and provide V&V assurance for system, subsystem and in focus EM-2 FSW (as identified in Appendix D) requirements through validation analysis (TF3) . This work is not expected to be completed in FY16t.
- Assess and provide initial V&V assurance for in focus FSW (as identified in Appendix D) Design (TF5) and Implementation (TF6) software and documentation analysis. This work is not expected to be completed in FY16.
- Assess and provide V&V assurance for software and information security as represented in architecture (TF2.6) and in-focus FSW requirements, design, code, and test software and documentation assuring preservation of the availability, integrity, and confidentiality for safety critical & mission critical capabilities.

AA-2: AA-2 is scheduled for launch in December of 2019. AA-2 is an uncrewed ascent abort test with the abort performed at the time of maximum dynamic pressure. AA-2 is launched on an expendable launch vehicle. AA-2 FSW development is scheduled to begin in FY16. This work will be performed by NASA civil servants in-house and not by the development team producing the EM-1 and EM-2 FSW. The schedule and development environment are currently being determined. Expected work in FY16 is:

- Work with the MPCV Program IV&V POC and representatives to identify, communicate and resolve risks, focusing on factors that are likely to impact IV&V and Program objectives in areas of performance, safety, schedule and cost.
- Work with the MPCV IV&V POC and representatives to identify, communicate, disposition and resolve technical issues in a timely and consistent manner, as a result of IV&V analyses performed throughout the fiscal year.
- Support management and technical reviews by assessing the review materials, attending the reviews, providing requested status and/or data to the Program, presenting at the reviews, and providing task reports and anomaly reports.
- IV&V will not provide assurance for the AA-2 test flight. IV&V analysis for AA-2 will be aimed at providing assurance for EM-2 and subsequent missions that will utilize the Ascent Abort FSW developed for test flight AA-2. Assess and provide V&V assurance for System, subsystem and FSW Concept & Architecture analysis (TF2).

G.2 FY 16 Targeted External Milestones

Table G-1: Program FY 16 Milestones

Key Milestone	Current Planned Date
< redacted >	< redacted >

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Key Milestone	Current Planned Date
< redacted >	< redacted >

* < redacted >

* < redacted >

G.3 FY 16 Internal Milestones

Table G-2: IV&V FY 16 Internal Milestones

Milestone	Current Planned Date
< redacted >	< redacted >

G.4 FY 16 Schedule

The IV&V MPCV project schedule and network diagram < redacted >

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G.5 FY 16 Risks

All MPCV IV&V identified risks are managed through the NASA IV&V 'Risk Manager' tool. Access to the tool and/or risk reports (for individual risks) from the tool can be obtained by contacting the MPCV IV&V NASA PM. The following table is a listing of all internal and external risks for the MPCV IV&V effort.

Table G-3: IV&V EM-1 Risks

< Table redacted >

G.6 FY 16 IV&V Deliverables

Table G-4: FY 16 IV&V Deliverables

Report Title or Scope	Delivery Date or timeframe
< redacted >	< redacted >

* < redacted >.

Appendix H: Fiscal Year 2017 to 2021 IV&V Efforts

H.1 FY 2017 to 2021 Goals/Objectives

The MPCV IV&V project objective for the years after FY16 is to complete independent verification and validation of the FSW needed to support EM-1, AA-2 and EM-2. Flight software developed and delivered as part of EFT-1 is expected to require additional verification and validation to retire the risks associated with the less rigorous processes applied to its development.

EM-1: EM-1 is scheduled for launch in September of 2018. The EM-1 mission is an uncrewed flight to a deep retrograde orbit several thousand miles beyond the moon's orbit. EM-1 is the first MPCV mission launched on the SLS. Prior to EM-1 launch:

- The ~45% of total MPCV FSW (previously delivered for EFT-1) will need to complete additional verification activities (primarily requirements, test documentation and implementation phase activities (TBR)) to retire risks associated with the development of EFT-1 FSW under EFT-1's lesser standards of rigor, and
- The ~25% of MPCV FSW uniquely associated with EM-1 and later flights will also need to complete development, verification and validation.

EM-1 will be supported by FSW Releases 22 through 27. Each release is an opportunity to provide test, design and implementation analyses of in phase artifacts. The actual analyses will be based on the maturity and stability of the associated artifacts for TF 4, TF 5 and TF 6 analyses.

AA-2: AA-2 is scheduled for launch in December of 2019. AA-2 is an uncrewed ascent abort test with the abort performed at the time of maximum dynamic pressure. AA-2 is launched on an expendable launch vehicle. AA-2 demonstrates the abort system's inflight performance prior to the crewed EM-2 flight.

- The 2% of the total MPCV FSW is new FSW needed for AA-2.
- The FSW Releases for AA-2 are currently scheduled to be releases 50 through 54.
- IV&V will not provide assurance for the AA-2 test flight. IV&V analysis for AA-2 will be aimed at providing assurance for EM-2 and subsequent missions that will utilize the Ascent Abort FSW developed for test flight AA-2.
- Specific activities for AA-2 for FY17-FY20 will address concept, requirements, test documentation, design and implementation V&V.

EM-2: EM-2 is scheduled for launch in December of 2020. EM-2 is a crewed lunar orbital mission launched on the SLS. Prior to EM-2 launch the 28% of the total MPCV FSW which is uniquely associated with EM-2 and later flights must complete development, verification and validation.

- The FSW Releases for EM-2 are currently scheduled to be Releases 62 through 65 and 70 through 75.
- Specific activities for EM-2 for FY16-FY21 will address concept, requirements, test documentation, design and implementation V&V.

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EM-3: EM-3 is scheduled for launch in August 2023 and will use a flight vehicle identical to the EM-2 vehicle.

- Specific activities for EM-3 are TBR but will address closure of requirements, test documentation, design and implementation V&V arising from flight experience.

EM-4: EM-4 is scheduled for launch in August 2025 and will use a flight vehicle identical to the EM-2 vehicle.

- Specific activities for EM-4 are TBR but will address closure of requirements, test documentation, design and implementation V&V arising from flight experience.

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H.3 FY2017 to FY2021 Internal Milestones

Table H-2: IV&V FY 17-FY21 Internal Milestones

Milestone	Current Planned Date
< redacted >	< redacted >

Project replanning (including updates and reviews of all associated documents) will be performed twice a year. The annual replanning activities will begin in the later portion of the third quarter of each fiscal year, and replanning will be completed prior to the beginning of the following fiscal year. Midyear planning activities will start in the second quarter and be completed prior to the start of the third quarter of the fiscal year.

H.4 FY 2017 to FY2021 Schedule

The IV&V MPCV project schedule presented in Section G.4 and network diagram, < redacted >

