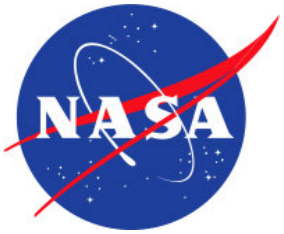
National Aeronautics and Space Administration



Independent Verification and Validation (IV&V)
JWST

IV&V Project Execution Plan (IPEP)
FY16 Version 8.0

Updated Date: 8/14/2015

NASA Independent Verification and Validation Facility
100 University Drive, Fairmont WV 26554

DOCUMENT COORDINATION and APPROVALS

This is Version 8.0 of the JWST IPEP. Changes to the body of this document (sections 1-4) will trigger an increase in the version number (i.e., Version 9.0) 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 9.0). 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 8.1). Draft versions of the IPEP will be marked as "DRAFT."

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<redacted>, JWST Project Manager

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

Table of Contents

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document conflicts with any document in the NASA Online Directives Information System (NODIS), this document shall be superseded by the NODIS document.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.

1 Introduction

1.1 Document Purpose

This IPEP has two primary purposes. First, it describes the overall JWST IV&V project and defines the basic agreements for the partnership between the JWST IV&V Team (hereinafter referred to as the IV&V Team) and the JWST Project (hereinafter referred to as the Project). These agreements include roles and responsibilities, communications paths, IV&V products, IV&V reporting methods, and artifacts anticipated to be shared between IV&V and the Project. Second, the IPEP serves as the operational plan for the IV&V efforts.

In signing this document, Project personnel understand their concurrence signature reflects the agreements identified within the body of the document, excluding the appendices. Signatures of NASA IV&V personnel attest 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 Project or until terminated at the request of the NASA IV&V Program or the Project.

1.2 Intended Audience

The intended audience of this document includes NASA IV&V Program staff, particularly the NASA IV&V Program Manager, IV&V Office (IVVO) management, and the IV&V Team; Project personnel, particularly the Project Manager, IV&V Point of Contact (POC), and Chief Safety Officer (CSO); Safety and Mission Assurance (SMA), and Information Security personnel.

1.3 Document Organization

The IPEP is divided into two major parts: the document body and the appendices. The document body describes the overall IV&V project and defines the basic agreements for the partnership between the IV&V Team and the Project. Once coordinated and approved, the basic agreements in the document body are not expected to change.

The second part of the document, the appendices, focuses 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 Project. The appendices include the results of, or a reference to, the IV&V Heritage Review, IV&V Portfolio Based Risk Assessment (PBRA) data and subsequent Risk Based Assessments (RBA), and detailed information for each planned execution year, including items such as IV&V goals and objectives, schedule, and risks.

2 IV&V Overview

2.1 IV&V Goals and Objectives

The IV&V Team will ascertain the "goodness of product" for the Project's safety and mission critical software. The IV&V Team will provide objective evidence and recommendations to increase the assurance that the software will operate reliably and safely in support of critical capabilities in the expected operating environment under nominal and defined off-nominal conditions. The IV&V Team will document any identified issues and risks to this assurance and will work with the Project to advance these issues and risks to resolution.

Specific IV&V project assurance goals and objectives for each fiscal year are identified in the appendices.

2.2 IV&V Approach

The IV&V Team functions technically, managerially, and financially independent of the Project. The IV&V approach will consist of validation- and verification-related analyses. Validation and verification are described further below, including the artifacts generally required for specific analysis objectives.

Validation-related analyses strive to assure the system software satisfies the user's capability needs under operational conditions. These analyses evaluate the attributes, features, and qualities exhibited by the Project's development artifacts for each selected critical capability, in the context of the following *three questions* defined in NASA IV&V SLP IV&V 09-1:
1) Will the software do what it is supposed to do?
2) Will the software not do what it is not supposed to do?
3) Will the software respond appropriately to adverse conditions?

Verification-related analyses determine whether the products of each development activity are of high quality (e.g., are clear, consistent, verifiable, correct, and complete) and fulfill the requirements or conditions imposed by a previous development activity.

Specific analyses that the IV&V Team may perform include verification and validation using the following types of Project artifacts: Concept Documentation, Requirements Documentation, Design Documentation, Test Documentation, Implementation, Security Documentation, and Operations and Maintenance Documentation. The analyses may examine software-associated aspects of cross-program interfaces, control centers, or major communication links to include command and data handling capabilities. The IV&V Team may also perform independent testing using simulators, test environments or other test systems provided by the IV&V Program or the Project.

Examples of artifacts the IV&V Team needs to support verification and validation related analyses are listed in Table 2-1, below. In the event 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 POC will closely coordinate any

impacts and document any risks to the performance of the IV&V efforts. The IV&V Team does not drive or mandate the creation of specific software artifacts. The IV&V Team will work with available information and content in most formats, as long as the artifacts provided include the data necessary to verify and validate the developer's software and 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 system software considering the Project's mission success criteria and the software's ability to perform or support expected system and software behaviors for critical capabilities.

Typical outputs of the verification and validation 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.

For additional information regarding verification and validation related analyses, see NASA IV&V System Level Procedure SLP IV&V 09-1, *Independent Verification and Validation Technical Framework.*

Table 2-1: Project Targeted Verification & Validation Artifacts

Artifact Name	**Need/Applicable Analysis**
Operations Concept Document/Data	Verify and Validate Software Requirements
Early concept/design review documentation/data	Verify and Validate Software Requirements
Level 1 requirements	Verify and Validate Software Requirements
Mission Requirements Document	Verify and Validate Software Requirements
Spacecraft Element Requirements Document	Verify and Validate Software Requirements
Software Requirements Document	Verify and Validate Requirements
Interface Requirements Documents	Verify and Validate Requirements
Traceability Related Data (L2 – L5)	Verify and Validate Requirements / Verify and Validate Test Documentation
Hazard Analyses (PHA, FTAs, etc.)	Verify and Validate Requirements / Verify and Validate Test Documentation
System Test Plan	Verify and Validate Test Documentation
System Test Cases	Verify and Validate Test Documentation
Build Level Test Plan	Verify and Validate Test Documentation
Build Level Test Cases	Verify and Validate Test Documentation
Integration Test Plans	Verify and Validate Test Documentation
Integration Test Cases	Verify and Validate Test Documentation
Traceability related data (showing traceability from requirements to test cases)	Verify and Validate Test Documentation
Software Design Documentation	Verify and Validate Design
Software Design Models	Verify and Validate Design
Source Code	Verify and Validate Implementation

Artifact Name	Need/Applicable Analysis
Software Build delivery/release packages/Version Description documentation/data	Verify and Validate Implementation
Test results (at varying levels including build level, integration level and system level)	Verify and Validate Test Documentation
Discrepancy reports from test activities	Verify and Validate Test Documentation
Traceability related data (showing traceability from requirements to design – to code to test)	Verify and Validate Test Documentation
Test Scripts	Verify and Validate Implementation
Compile and build procedures	Verify and Validate Implementation
Build environments	Verify and Validate Implementation
Test environment resources (e.g., simulators)	Verify and Validate Implementation
System Security Plan	Verify and Validate Software Security
Software Security Requirements (if separate)	Verify and Validate Software Security
Software-related Security Test Cases (if separate)	Verify and Validate Software Security

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, reliability, and quality of software systems. To understand the risk profile, IV&V performs an independent software risk assessment to satisfy the following two objectives:

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

The IV&V Team uses the PBRA process to assess the required system capabilities for which software contributes, in terms of impact of a defect and likelihood of a defect. The result of this assessment is an overall rating for each capability that is mapped using a 5x5 risk matrix to prioritize the IV&V efforts within a particular IV&V project. This prioritization ensures application of IV&V resources to the most critical software capabilities.

The RBA process is used to select critical software entities (e.g., CSCIs) to further plan and scope the IV&V project. The 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 the PBRA and RBA results with Project and Agency stakeholders. Input and feedback on this data from the Project is encouraged. The IV&V Team will revisit the assessment ratings for the Project every six months (or more frequently, if warranted), and any changes to this data will be communicated to the Project. PBRA results are provided in

Appendix A, and RBA results are provided in Appendix B. For additional information on the PBRA and RBA process, see NASA IV&V guidelines for the PBRA and RBA Process, S3106.

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 Project. The subsections below describe these roles and responsibilities. Figure 3-1 depicts the interfaces associated with these roles.

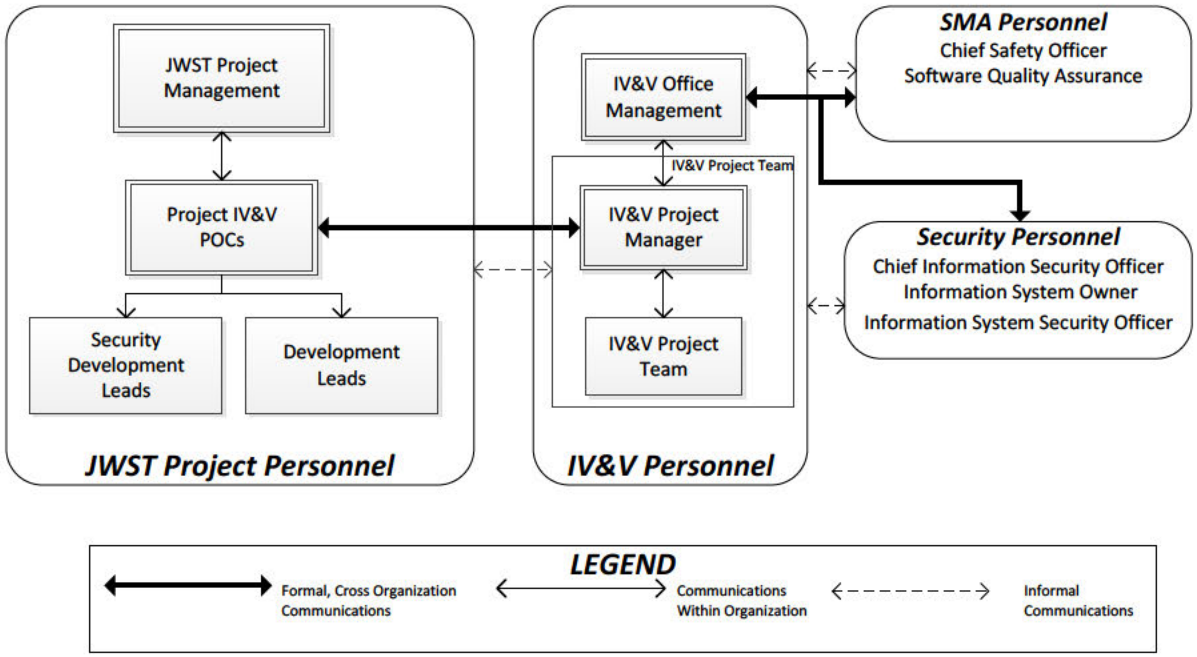


Figure 3-1 – IV&V Team and Project Interfaces

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 efficiency and effectiveness of IV&V. All Project data will be closely protected and not released outside the NASA IV&V Program and its research contractors. No proprietary Project 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. The Project agrees that non-proprietary, non-export-controlled, non-SBU Project data may be used to support software IV&V-related research. The NASA IV&V Program agrees that any related research will not affect Project 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 Project without specific, prior written approval from the Project.

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 identified by IV&V and software issues identified by the Project, as well as investigating post-launch software anomalies. The IV&V Team may request data from the Project in support of these efforts. The Project, subject to the IV&V POC'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 POC 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
(b) Post-launch software anomalies: description of the software issue, overall impact, relevant CSCI, root or contributing cause, associated resolution to the defect anomaly

Access to the data can be in the form of access to Project or 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 Project.

3.2 IV&V Team

The IV&V Team primarily consists of a NASA IV&V PM, IV&V DPM, and an IV&V Analyst Team. For the JWST mission, the IV&V PM serves as the primary interface with the Project in support of the IV&V efforts. The IV&V PM is responsible for the overall leadership and direction of the IV&V efforts; however, the IV&V DPM has an integral role in assisting the IV&V PM, and is directly responsible for interfacing with the project and providing leadership and direction for the JWST Ground related IV&V efforts.

This IPEP is prepared and maintained by the IV&V 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 Project). 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 Project as defined in this plan are met.

The IV&V Analyst Team performs the verification- and validation-related analysis. At times and at the request of the IV&V PM, the IV&V analysts may interface with the Project. Informal interfaces between IV&V Personnel, including members of the IV&V Analyst Team, and Project, SMA, and Information Security personnel are indicated by the dashed lines in Figure 3-1. Development of informal interfaces is encouraged to enhance communications and resolve concerns and questions at the lowest possible level.

A variety of different NASA IV&V Program groups may support the IV&V Team, and personnel from these groups may interact with Project, SMA, and Security personnel, as coordinated by the IV&V PM. Supporting groups may include the NASA IV&V Program

Independent Test Capability (ITC) team and the IV&V Software Assurance and Tools team (SWAT).

3.3 Project Personnel

The Project will provide an IV&V POC for formal interactions between the IV&V Team and the Project. The Project IV&V POC will facilitate the IV&V tasks to be performed through coordination between Project personnel, the Project's Safety and Mission Assurance (SMA) personnel, the Project's Information System Security Officer, the development leads, and the IV&V PM.

The Project will provide the IV&V Team the necessary interfaces, Project development data and documentation, and any other negotiated resources to perform the IV&V tasks. The Project will provide such data and documentation as the information is made available to the Project. The Project will provide draft and final versions of IV&V-negotiated 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 Project IV&V POC 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 Project. 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 Project data and documentation is preferred (e.g., requirement tracing tools and databases, issue tracking systems, document repositories, risk management system, etc.).

The Project, through the IV&V POC, is responsible for working with the IV&V Team to resolve issues and risks identified by the IV&V Team.

The Project, through the IV&V POC, will support any research and metrics related initiatives as described above.

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

Table 3-1 – IV&V Team Contact Information

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

NASA IV&V Program		
Position	**Name**	**Contact Information**

Table 3-2 – Project Contact Information

Project		
Position/Role	**Name**	**Contact Information**
<redacted>	<redacted>	<redacted>

4 IV&V Products and Communication and Reporting Methods

The IV&V Team generates various products and utilizes various communication and reporting methods throughout the lifecycle. The subsections below describe the IV&V products and associated communication and 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 (Project artifacts), a high-level description of the process, approach, and tools used (if applicable), and associated results. The IV&V Team will provide the analysis reports to the Project as defined in the Appendix for each fiscal year.

4.1.2 Lifecycle Review Presentations

Throughout the lifecycle, the IV&V Team supports formal Project milestone reviews (e.g., a Preliminary Design Review, a Critical Design Review (CDR), etc.) by providing information that portrays the IV&V assurance status, 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 Safety and Mission Success Review (SMSR).

4.1.3 Technical Issue Memorandums

A Technical Issue Memorandum (TIM) is the formal mechanism the IV&V Team uses to document one or more instances of a defect or defects (i.e., issue) identified within a development artifact, and subsequently formally communicate defects to the Project. Each TIM has a documented impact and is assigned a severity rating between 1 (highest severity) and 5 (lowest severity) as defined in Table 4-2. TIMs of severity rating 1-3 require a formal disposition by the Project and must be verified to have been addressed prior to closure. TIMs of severity rating 4 or 5 may be reviewed by the Project, but a formal response is not required (i.e., may transition directly to the "Not To Be Verified" state in IV&V Program issue tracking system). Resolving severity rating 4 and 5 TIMs, nonetheless, will certainly improve the quality of the Project's software and reduce or eliminate risks associated with maintenance of the software product.

TIM Resolution Path: The Project will review the TIM as provided by the IV&V Team and respond in a timely manner. Timing may require coordination on a case-by-case basis. In general, it is best if TIM can be reviewed and responded to within a couple of weeks. Timely Project review and response is important to avoid propagation of defects into subsequent Project products, to prevent incorrect IV&V reporting (e.g., to Office of Safety and Mission Assurance (OSMA) and other NASA IV&V Program stakeholders), and to minimize IV&V rework.

If the Project concurs that a TIM is legitimate, the Project will propose a solution or formally accept the risk of not resolving the issue. IV&V does not advocate for the acceptance of risk associated with Severity 1 or 2 TIMs. When the Project identifies a plan to fix the defect, the TIM will be put in the "To Be Verified" state. After the defect is resolved, the Project 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 TIM. If verification of the corrective action cannot be completed, the IV&V Team will request additional information from the Project. If the Project accepts the risk of not resolving the TIM, the TIM will be put in the "Project Accepts Risk" state.

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

If the Project does not concur a TIM is legitimate, the Project will provide appropriate data and/or explanation to support this conclusion. The IV&V Team will review and consider this data. If the IV&V Team agrees, the TIM will be withdrawn. If the IV&V Team does not agree, additional dialog and discussion between the Project and IV&V Team may be required and an appropriate course of action will be determined.

Table 4-2: TIM Severity Rating and Description[1]

Severity	Capability Affected	Success Criteria	Safety	Test	Cost & Schedule	Other
1 Catas-trophic	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 accomplish-ment 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 accomplish-ment of extended/ optional mission objectives	N/A	Essential capability inadequately tested	Cost or schedule impact resulting from redesign, reimplemen-tation, 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 Communi-cations Or Editorial	Defect impacting documentation and communication clarity and poses no risk to the Mission Project					

[1] Source: S3105, Guidelines for Writing IV&V TIMs. Refer to this guideline for definitions of terms used above.

4.1.4 Risks

By conducting IV&V analysis, the IV&V Team may become aware of circumstances or information that represents a potential undesirable event for the Project. The IV&V Team will document such items as risks and will formally communicate these risks to the Project. The IV&V Team will assess all risks based on the likelihood and consequence of the undesired event using the Project's likelihood and consequence ranking criteria (as defined in the Project'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 Project prior to formal submission. To facilitate the submission of risks, the IV&V Team may request access to the Project's Risk Management System (RMS) and the IV&V Team and IV&V POC will work together to determine the appropriate level of access (e.g., read-only, write, none) to the RMS.

Typically, Projects retain residual risks throughout the lifecycle. As such, the IV&V Team may need to assess the Project'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 Project in preparation for the SMSR. The IV&V Team will communicate their stance with regards to such residual risk data to the Project prior to the SMSR.

Risk Resolution Path: The Project will review risks as provided by the IV&V PM. If the Project agrees with the nature of the risk they may choose to take ownership of the risk. Subsequently, the Project will document the risk and associated mitigation plan(s) in the Project's RMS. It is expected that the Project actively manages, tracks, and mitigates such risk. The IV&V Team will monitor the progress of these activities until the risk is closed. This monitoring may be performed independently or via the Project 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 Project IV&V POC and determine an appropriate course of action.

If the Project decides not to accept, mitigate, and manage a risk, the Project will provide appropriate information to support this conclusion. The IV&V Team will review this information 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 between the Project and IV&V Team may be required and an appropriate course of action will be determined.

4.1.5 Item Tracking, Monitoring, and Escalation

All data such as issues and risks are recorded and provided to the Project as they are identified and/or as per an agreed-to schedule. The IV&V Team will evaluate Project responses to this data and update the status of this data in terms of tracking towards resolution in the appropriate NASA IV&V Program repository. 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 or 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 Project 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 Project is aware that the issue is being elevated. The final level of resolution will be the Program Management Council (PMC) responsible for the Project.

4.2 IV&V Communication and Reporting Methods

Communications and reporting methods between the IV&V Team and the Project occur via both formal and informal channels. Formal communication and reporting methods include delivery of IV&V analysis reports and associated technical data, IV&V briefings at milestone reviews, and dialog between the IV&V Team and Project regarding scope, priorities, access to resources, etc. consistent with this plan. Informal communications and reporting methods include recurring teleconferences and tag-ups between the IV&V Team and Project IVV POC, requests for and delivery of development artifacts, technical discussion on IV&V analysis results 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 of the IV&V efforts at various Project milestone reviews as defined in Table 4-3 below. The IV&V Team will communicate and coordinate the overall content of the presentation with the Project prior to the actual review.

Table 4-3: Milestone Review IV&V Presentations

Milestone Review	Project Recipient	Input Due
Test Readiness Reviews	IV&V POC	As required
Design Reviews	IV&V POC	As required
System Integration Reviews	IV&V POC	As required
Pre-Ship Reviews	IV&V POC	As required
Safety and Mission Success Review	IV&V POC	As required

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 and the Mission Directorates. Given that the IV&V Program is GSFC Code 180.0, IV&V does provide input to the GSFC Monthly Status Reviews for all projects receiving services from the IV&V Program. The IV&V Team will communicate and coordinate the overall content of these presentations with the Project prior to the actual review as defined in Table 4-4 below.

Table 4-4: Additional Reporting Events

Milestone Review	Project Recipient	Input Due
Monthly Status Review (MSR)	IV&V POC	JWST IV&V inputs provided 5 working days prior to review
Science Mission Directorate (SMD) Pre-Brief to the IV&V Board of Advisor (IBA) Semi-Annual Briefings	IV&V POC	JWST IV&V inputs provided prior to review

4.2.3 Routine Tag-ups

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

Appendix A: IV&V Portfolio-Based Risk Assessment (PBRA) Results

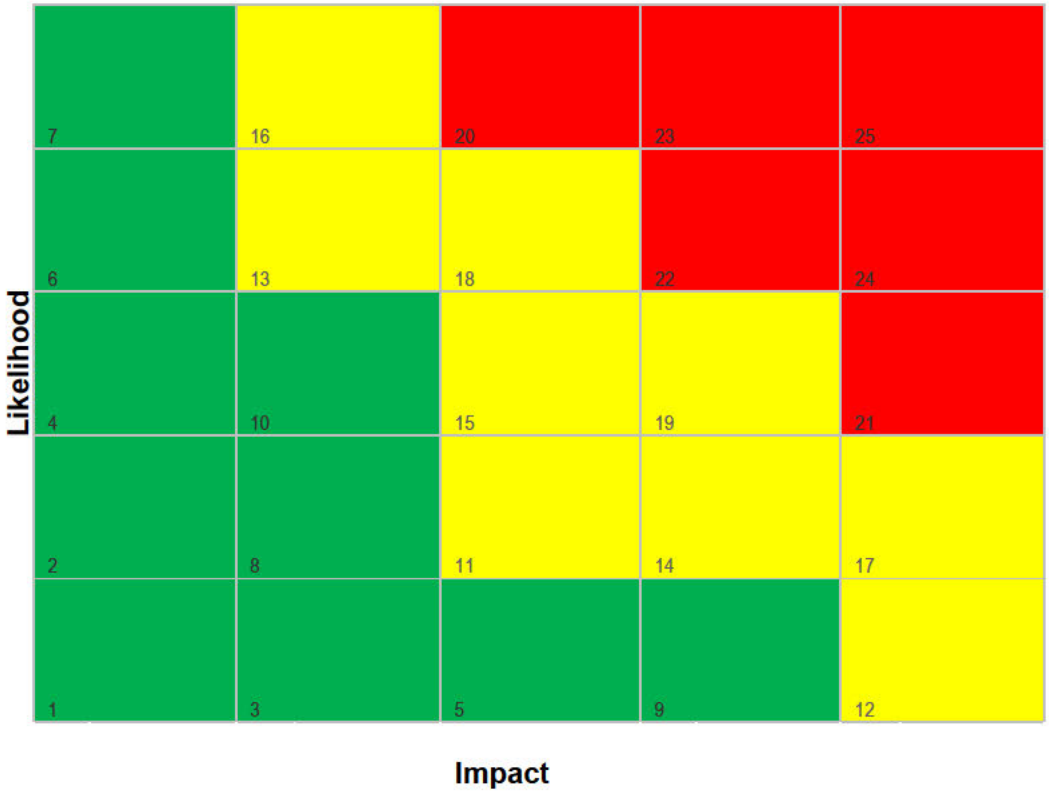
The JWST PBRA results help prioritize and focus IV&V activities at a system-capability level. Table A-1 shows the Impact and Likelihood scores for each PBRA capability. Scores are on a scale of 1-to-5.

Table A-1 PBRA Results for JWST

<Table Redacted>

Figure A-1 shows each capability plotted on the 5x5 risk matrix and the basis of the "red", "yellow", or "green" risk rating.

Figure A-1 PBRA 5x5 Risk Matrix



<Risks Redacted>

Although color is not the only discriminating factor, capabilities rated "green" will not receive IV&V directly. Capabilities rated "yellow" will receive IV&V. Capabilities rated "red" will receive IV&V, but typically with a higher priority than "yellow".

Appendix B: IV&V Risk Based Assessment (RBA) Results

Similar to the PBRA, the JWST RBA results help prioritize and focus IV&V activities for the software entities. Entity names typically correspond to the names assigned by JWST developers. These can be at the Computer Software Configuration Item (CSCI) level, but are typically decomposed to the Computer Software Component (CSC) level or lower.

Table B-1 provides the scores and ratings for each RBA entity. As with the PBRA, the colors denote the IV&V risk rating. The nominal approach to IV&V analysis is follows:

- Red entities – full lifecycle IV&V analysis (requirements, design, code, and test artifacts) with emphasis on functions that support red and yellow PBRA capabilities
- Yellow entities – requirements analysis, test analysis, and code quality assessment (i.e., via static code analysis); for yellow components with high RBA impact scores (>3) or areas where latent risk/concerns were identified by other analysis tasks or data, targeted design and code analysis will also be performed
- Green entities – no IV&V analysis unless warranted by latent risk/concern identified during analysis tasks defined in this IPEP or from new data that raises question over green rating

Table B-1 – JWST RBA Results

<Table redacted>

Figure B-2 – JWST Capability to Entity Mapping (Excerpt)

<Table redacted>

A mission scenario can be used to represent an instantiation of a capability. The capabilities-to-entities relationships can help isolate the entities that support a given mission scenario. The IV&V Team may use mission scenarios for one or more of the following purposes:

1. Provide a contextual reference for a planned analysis activity
2. Relate analysis results to assurance objectives
3. Ensure analysis emphasis is from a three questions perspective
4. Provide a mechanism to focus or prioritize IV&V rigor

[redacted].

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

JWST IV&V Heritage Review

The purpose of the JWST IV&V Heritage Review was to survey analysis results from prior IV&V projects for applicability to JWST and to document references to applicable results for use in JWST IV&V work. This activity occurred in 2010. The results are captured in a report maintained [redacted].

Applicable Lessons Learned

The purpose of this section is to identify lessons learned on previous missions that have applicability to JWST. Lessons learned may have been captured in previous versions of the IPEP, but are retained for reference and as an indication of the JWST IV&V Team's commitment to continuous improvement.

The IV&V Facility Lessons Learned database contains several lessons learned that are applicable or at least partially applicable:

- **Facilitating Access to Artifacts –** This lesson suggests that having IV&V analysts collocated with the development effort provides the best option for facilitating IV&V access to artifacts. Because of the distributed nature of the JWST development effort (including developers in other nations), it is not possible collocate with all development sites. The project has been willing to provide JWST IV&V with electronic access to development repositories, which has been a necessary part of doing business since it has been more convenient to pass IV&V results to developer via their repositories than to coordinate encrypted email. In the coming year, JWST IV&V intends to expand the number of analysts who have direct access to artifact repositories to avoid access bottlenecks where only a few have direct access to the artifact repository. Distributed access will require distributed responsibility for ensuring the correct versions of artifacts are used and artifacts are protected from inadvertent data corruption. The JWST Team will work to establish procedures for artifact handling under the mode of expanded direct access for analysts. Where possible, the JWST IV&V Team will take advantage of location to facilitate communications with the project, attendance at reviews and meetings, and early access to artifacts, such as with the team members who work on site at GSFC and the project and development activities at or nearby GSFC.
- **Scenario Development –** This lesson identifies the value of identifying scenarios to be used for analysis early, and to maintain them. Early in the project during requirements validation, the JWST IV&V Team identified system scenarios and documented them as use cases. The developers of the system test cases welcomed this as input to the end-to-end system test plan, which serve as an example of value added to the Project. Scenarios continue to serve as an integral part of the IV&V Technical Reference used through the IV&V lifecycle. Risk reduction scenarios are a special class of scenarios used as the basis of independent testing.

  IV&V analysis of the On Board Fault Management (OBFM) application uses a custom database that links software states, FMEA data, FTA data, and requirements. This data is used to prioritize scenarios and track the assurance achieved through them.

There are applicable lessons that the JWST IV&V Team is aware of through the past affiliation of some team members with the ISS IV&V project:

- **Lessons from ISS IV&V Independent Testing –** The ISS IV&V Team has a long history of performing independent testing. The JWST IV&V Team continues to leverage lessons learned about independent testing from ISS IV&V including:
    - **Test Identification –** Independent testing is not intended to duplicate the testing that has been accomplished by the developers. The IV&V Team should use a number of perspectives to identify candidate tests that can explore areas of residual risk of software defects. Candidate test scenarios should be prioritized based on the impact any defects would have, and the feasibility of assuring the software through code analysis and the feasibility of implementing the test scenarios in the available test bed. In addition to considering candidate tests from gaps in developer testing, the test team should consider negative predicates, off-nominal/fault injection tests, interface tests, repeatability (back-to-back scenarios), stress tests, extended duration tests, concurrent processing and function interaction tests, and operational scenarios. Based on code coverage, analysts should consider tests for untested or under-tested code. For recent flight software updates due to code issues, analysts should consider tests to explore change impacts, similar problems in other areas of the code, and the potential for undiscovered issues in the neighborhood of identified issues.
    - **Test Plan Documentation –** IV&V test plans should be documented, and should include an initial set of test cases. Since one benefit of IV&V testing is increased system understanding, the test plan should include a provision for ad-hoc testing and include a description of the process for identifying additional test cases. The goal of ad-hoc testing is to have an approach that is responsive to new clues and questions that arise about the software implementation or its behavior, not to exercise the code in ways that it is not intended to be used. One expected use for ad-hoc testing is to answer questions about the correctness of the implementation that arise through code analysis, especially ones that are not easy to answer without running the code. Often, there are valid scenarios that are not explicitly addressed in the requirements once details of the design and implementation are known. Ideally, the requirements should be updated to cover these cases, but at a minimum, the credible scenarios should be exercised so the behavior can be evaluated as to whether it meets the needs (or operators at least know what to expect).The test plan should also include a description of the test bed hardware and software components, and a description of the test bed certification process that establishes confidence that the test bed results will reliably represent flight software anomalies and not be due to problems with the test bed configuration.
    - **Test Anomaly Handling –** Once a test anomaly is observed, the IV&V test team must evaluate the anomaly to generate evidence that the anomaly is due to a flight software defect rather than a test bed configuration issue. Anomalies are reviewed in the context of the system/software requirements and operational concepts. Methods that should be used for anomaly investigation include: re-running the test to establish repeatability, conducting a review of the test bed configuration for unintended changes, re-running developer tests to confirm the stability of the test bed, analyzing the source code to attempt to confirm the cause of the anomaly,

and running additional scenarios that exercise the function where the anomaly occurred to pinpoint the conditions that trigger the anomaly. Through this post-test scrutiny, an attempt is made to discern whether the anomaly is due to the test bed configuration, the test scenario executed, or the code under test. Only when convinced that the operational code is the source of the anomaly, and it is not behaving as intended, will the anomaly be documented as an issue.

Appendix D: Technical Scope and Rigor

JWST IV&V Technical Scope & Rigor (TS&R) document is stored [redacted]. This site is only available to IV&V personnel. The TS&R document identifies the analysis methods selected and scope for the planned IV&V activities. The document is typically not provided to external stakeholders. However, a copy can be provided upon request.

Appendix E: Reference Documentation

Table E-1 lists processes and standards applicable to the JWST IV&V project.

The official JWST Project artifact repository can be found at: [redacted]

Table E-1: Relevant Documentation

Document	Title	Link or Date
IVV 09-01	Independent Verification and Validation Technical Framework, Revision O	IVV 09-01
S3105	Guidelines for Writing IV&V TIMs	S3105
S3106	PBRA and RBA Process	S3106
NASA-STD-8719.13B	NASA Software Safety Standard	NASA-STD-8719.13B
NPR 8715.3C	NASA General Safety Program Requirements	NPR 8715.3C
NPR 7150.2B	NASA Software Engineering Requirements	NPR 7150.2B

For more information regarding the JWST mission, see the Project's website at: http://www.jwst.nasa.gov/

Appendix F: Acronyms

ACS	Attitude Control Subsystem
ADU	Actuator Deployment Unit
ARD	Algorithm Requirements Document
BTA	Branch Terminal Analysis
CC	Cryo Cooler
CCE	Cryocooler Control Electronics
C&DH	Command and Data Handling
CDR	Critical Design Review
CSCI	Computer Software Configuration Item
CSO	Chief Safety and Mission Assurance Officer
DEU	Deployment Electronics Unit
DI	Dictionary Interface
DMS	Data Management System
DS	Detector Subsystem
DSS	Detector Subsystem Software
EPS	Electrical Power Subsystem
FGS	Fine Guidance Sensor
FM	Fault Management
FMAD	Fault Management Algorithms Document
FMEA	Failure Modes Effect Analysis
FMECA	Failure Mode Effects and Critical Analysis
FOS	Flight Operations System
FSW	Flight Software
FTA	Fault Tree Analysis
GS	Ground Segment
IBA	IV&V Board of Advisors
ICD	Interface Control Document
IPEP	IV&V Project Execution Plan
IRCD	Interface Requirements Control Document
IRD	Interface Requirements Document
ISIM	Integrated Science Instrument Module
ISS	International Space Station
ITC	Independent Test Capability
IV&V	Independent Verification and Validation
IVVO	IV&V Office
JIST	JWST IV&V Simulation and Test
JPIM	JWST Payload Interface Module
JWST	James Webb Space Telescope
MAP	Microwave Anisotropy Probe
MCFSWA	MIRI Cooler Flight Software Application
MCS	Mirror Control Software
MDL	Mission Directorate Lead
MIRI	Mid-Infrared Instrument

MIRI OS	MIRI Optical System
MMS	Mirror Management Software
MPS	Mission Preserving Scenario
MRR	Mission Readiness Review
MSR	Monthly Status Review
MSS	Micro Shutter Subsystem
NASA	National Aeronautics and Space Administration
NC	Near-Infrared Camera
NGAS	Northrop Grumman Aerospace Systems
NIRCam	Near-Infrared Camera
NIRSpec	Near-Infrared Spectrograph
NIRISS	Near-Infrared Imager and Slitless Spectrograph
NLT	No Later Than
NODIS	NASA Online Directives Information System
NS	Near-Infrared Spectrograph
OBFM	On Board Fault Management
OSS	Operations Script Subsystem
OTE	Optical Telescope Element
PBRA	Portfolio Based Risk Assessment
PHA	Preliminary Hazard Analysis
PDR	Preliminary Design Review
PL	Project Lead
PM	Project Manager
PMC	Program Management Council
POC	Point of Contact
PPP	Project Protection Plan
PPS	Proposal Planning System
PRDS	Project Reference Database System
PTS	Project Threat Summary
RBA	Risk Based Assessment
RMO	Resource Management Office
RMS	Risk Management System
SBU	Sensitive But Unclassified
S/C	Spacecraft
SC	Spacecraft
SCE	Spacecraft Element
SCS	Stored Command Sequence
SDO	Solar Dynamics Observatory
SMA	Safety and Mission Assurance
SMSR	Safety and Mission Success Review
S&OC	Science and Operations Center
SQA	Software Quality Assurance
SRM	System Reference Model
SRS	Software Requirements Specification
SSP	System Security Plan

SUROM	Start Up Read Only Memory
TBD	To Be Determined
TCS	Thermal Control Subsystem
TIM	Technical Issue Memorandum
TQ&E	Technical Quality and Excellence
TS&R	Technical Scope and Rigor
V&V	Verification and Validation
WAS	WFS&C Analysis Software
WBS	Work Breakdown Structure
WEx	WFS&C Executive
WFS&C	Wave Front Sensing and Control
WSS	WFS&C Software Sub-System

Appendix G: Fiscal Year FY16 IV&V Efforts

G.1 FY16 Goals/Objectives

For FY16, the JWST IV&V Team expects to conduct the IV&V analysis objectives listed below. Focus will be placed on the in-scope capabilities and entities per Appendix A and Appendix B. Table G-1 identifies the FY16 verification and validation analysis targets of each objective

- Verify and Validate Requirements
  - Analyze the software requirements to assure that the right behaviors have been defined and that the specifications are of high quality. Assure that requirements specify appropriate corrective and preventative actions to off-nominal conditions (i.e., responses to credible faults and failures).
- Verify and Validate Software Design
  - Assess the software design to assure it adequately satisfies the validated requirements, including dependability and required fault tolerance requirements.
- Verify and Validate Test Design
  - Ascertain scope and completeness of test approach; assure the test program is robust and tests functional and non-functional requirements. Assure tests verify both the positive and negative perspectives of the requirements, as well as verify both sides of upper and lower limits where applicable.
- Verify and Validate Software Implementation
  - Assure the source code is high quality by applying static code analysis.[*]
  - Assure that the implementation complies with software design and requirements, including dependability and required fault tolerance requirements, and the implementation does not include undocumented behaviors by code inspection.[†]
- Verify and Validate Software Integration
  - Assess software integration risks and provide assurance for software integration concerns, including analysis of developer integration testing, analysis of software interactions, assurance of end-to-end fault management software capabilities.
  - Maintain assurance status through change impact analysis for software components as integration-driven changes are made.
- Verify and Validate Software Security
  - Assess information security-related requirements, design, code, and test artifacts, in the context of software. Assure the software preserves the availability, integrity, and confidentiality for safety critical & mission critical capabilities.
- Validate Software via Independent Test
  - Assure the mission and safety critical software performs as expected when subjected to independent test, and that software does not exhibit any undesirable behaviors. The primary approach is to independent test the software using the

[*] Corresponds to "1" in the key for Table G-1
[†] Corresponds to "2" in the key for Table G-1

JWST IV&V Simulation and Test (JIST) simulation by applying a series of risk reduction scenarios. There is no intent to duplicate or obviate the need for testing performed by the project.

Table G-1: IV&V FY 16 Analysis Targets

<Table redacted>

G.2 FY16 Targeted External Milestones

Table G-2: Project FY16 Milestones

Key Milestone	Current Planned Date
<redacted>	<redacted>

G.3 FY16 Internal Milestones

Table G-3: IV&V FY16 Internal Milestones

Milestone	Current Planned Date
<redacted>	<redacted>

<redacted>	<redacted>

G.4 FY16 Deliverables

Table G-4: FY16 IV&V Deliverables

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

G.5 FY16 Schedule

The JWST IV&V Schedule (JIMS) is a dynamic management tool and is subject to changes in the JWST Project schedule. JWST has multiple sources of schedule data, which are incorporated into JIMS as they become available.

JWST FY16 schedule is stored on the IV&V Facility shared network drive at: <redacted>. This site is only available to IV&V personnel. However, JIIMS snapshots can be provided to external stakeholders upon request.

G.6 FY16 Risks

This section summarizes the open external and internal risks at the time of the FY16 IPEP release.

Table G-3: IV&V Identified Risks

<Tables redacted>

Appendix I: Fiscal Year FY17 IV&V Efforts

I.1 FY17 Goals/Objectives

For FY17, the JWST IV&V Team expects to conduct the IV&V analysis objectives listed below:

- Verify and Validate Requirements
  - Analyze the software requirements to assure that the right behaviors have been defined and that the specifications are of high quality. Assure that requirements specify appropriate corrective and preventative actions to off-nominal conditions (i.e., responses to credible faults and failures).
  - Focus will be placed on the in-scope behaviors, per the PBRA/RBA with planned support for the following:
    - OSS and SCS
- Verify and Validate Test Design
  - Ascertain scope and completeness of test approach; assure the test program is robust and tests functional and non-functional requirements. Assure tests verify both the positive and negative perspectives of the requirements, as well as verify both sides of upper and lower limits where applicable.
  - Focus will be placed on the in-scope behaviors, per the PBRA/RBA with planned support for the following:
    - FOS, OSS, and SCS
- Verify and Validate Software Design
  - Assess the software design to assure it adequately satisfies the validated requirements, including dependability and required fault tolerance requirements.
  - Focus will be placed on the in-scope behaviors, per the PBRA/RBA with planned support for the following:
    - <redacted>
- Verify and Validate Software Implementation
  - (1) Assure the source code is high quality by applying static code analysis (2) Assure that the implementation complies with software design and requirements, including dependability and required fault tolerance requirements by code inspection. Assure the implementation does not include undocumented behaviors.
  - Focus will be placed on the in-scope behaviors, per the PBRA/RBA with planned support for the following:
    - <redacted>
- Verify and Validate Software Integration
  - Assess software integration risks and provide assurance for software integration concerns, including analysis of developer integration testing, analysis and independent testing of software interactions, assurance of end-to-end fault management software capabilities.
  - IV&V assessment <redacted>

  - Maintain assurance status through change impact analysis for software components as integration-driven changes are made: <redacted>.
- Verify and Validate Software Security
  - Provide assurance for software and information security for requirements, design, code, and test software and documentation assuring preservation of the availability, integrity, and confidentiality for safety critical & mission critical capabilities.
  - Maintain assurance status through change impact analysis
- Validate Software via Independent Test
  - Assure the mission and safety critical software performs as expected when subjected to independent test. This will be applied to areas where additional rigor is warranted and supported by JIST.
- Verify resolutions of TIMs

I.2 FY17 Targeted External Milestones

Table I-1: Project FY17 Milestones

Key Milestone	Current Planned Date
<redacted>	<redacted>

I.3 FY 17 Internal Milestones

Table I-2: IV&V FY17 Internal Milestones

Milestone	Current Planned Date
<redacted>	<redacted>

I.4 FY17 Schedule

The FY17 schedule will be developed and made available following the JWST FY17 planning session in late FY16.

I.5 FY17 Risks

Table I-3: IV&V Identified Risks

Risk Title	Risk Statement/Description
None identified at this time	

I.6 FY17 IV&V Deliverables

Table I-4: FY17 IV&V Deliverables

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

Appendix J: Fiscal Year FY18 IV&V Efforts

J.1 FY18 Goals/Objectives

For FY18, the JWST IV&V Team expects to conduct the IV&V analysis objectives listed below:

- Verify and Validate Test Design
  - Ascertain scope and completeness of test approach; assure the test program is robust and tests functional and non-functional requirements. Assure tests verify both the positive and negative perspectives of the requirements, as well as verify both sides of upper and lower limits where applicable.
  - Focus will be placed on the in-scope behaviors, per the PBRA/RBA with planned support for the following:
    - <redacted>
- Verify and Validate Software Integration
  - Assess software integration risks and provide assurance for software integration concerns, including analysis of developer integration testing, analysis of software interactions, assurance of end-to-end fault management software capabilities.
  - Maintain assurance status through change impact analysis for software components as integration-driven changes are made: <redacted>.
- Verify and Validate Software Security
  - Assess and provide assurance for software and information security for requirements, design, code, and test software and documentation assuring preservation of the availability, integrity, and confidentiality for safety critical & mission critical capabilities.
  - Maintain assurance status through change impact analysis
- Validate Software via Independent Test
  - Assure the mission and safety critical software performs as expected when subjected to independent test. This will be applied to areas where additional rigor is warranted and supported by JIST.
- Verify resolutions of TIMs
- Begin development of JWST IV&V Final Report

J.2 FY18 Targeted External Milestones

Table J-1: Project FY18 Milestones

Key Milestone	Current Planned Date
<redacted>	<redacted>

J.3 FY18 Internal Milestones

Table J-2: IV&V FY18 Internal Milestones

Milestone	Current Planned Date
<redacted>	<redacted>

J.4 FY18 Schedule

The FY18 schedule will be developed and made available following the JWST FY18 planning session in late FY17.

J.5 FY18 Risks

Table J-3: IV&V Identified Risks

Risk Title	Risk Statement/Description
None identified at this time	

J.6 FY18 IV&V Deliverables

Table J-4: FY18 IV&V Deliverables

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