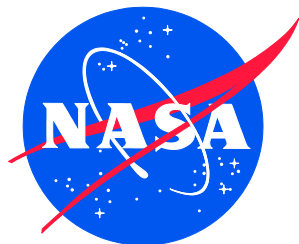


NASA/TM-2014-218278
NESC-RP-14-00938



Review of Ground Systems Development and Operations (GSDO) Tools for Verifying Command and Control Software

*Michael L. Aguilar/NESC
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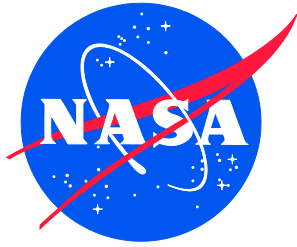
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Space Administration

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June 2014


Acknowledgments

The team would like to thank the GSDO Program and Command, Control, Communications, and Range points of contact (Kirk Lougheed, Christie Best, Robert Waterman, and Patricia Nicoli) for their cooperation and for providing the wealth of reference material—essentially more than 20 design, interface, and requirements documents, including the Space Launch System (SLS)-GSDO emulator and simulator bilateral exchange agreement. A very special thanks to Christie Best and her team for their quick responses to the many requests for data and clarifications related to the technical design.

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|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 1 of 27 | |

**Review of Ground Systems Development and
Operations (GSDO) Tools for Verifying
Command and Control Software**

May 1, 2014

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | | Page #: 2 of 27 |

Report Approval and Revision History

NOTE: This document was approved at the May 1, 2014, NRB. This document was submitted to the Acting NESC Director on May 14, 2014, for configuration control.

| | | |
|-----------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| Approved: | <i>Original Signature on File (DS)</i> <hr style="border: none; border-top: 1px solid black;"/> Acting NESC Director | <i>5/19/14</i> <hr style="border: none; border-top: 1px solid black;"/> Date |
|-----------|-------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|

| Version | Description of Revision | Office of Primary Responsibility | Effective Date |
|---------|-------------------------|-----------------------------------------------------------------------|----------------|
| 1.0 | Initial Release | Michael L. Aguilar, NASA Technical Fellow for Software, GSFC | 5/1/14 |



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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 3 of 27 | |

Table of Contents

Technical Assessment Report

| | | |
|-------------|---------------------------------------------------------------------------|-----------|
| 1.0 | Notification and Authorization | 5 |
| 2.0 | Signature Page | 6 |
| 3.0 | Team List | 7 |
| 3.1 | Acknowledgements..... | 7 |
| 4.0 | Executive Summary | 8 |
| 5.0 | Assessment Plan | 9 |
| 6.0 | Problem Description, Proposed Solutions, and Risk Assessment | 9 |
| 7.0 | Data Analysis | 10 |
| 7.1 | Source Documents for this Assessment..... | 11 |
| 7.2 | Review Process..... | 18 |
| 7.2.1 | Generate Component Structure..... | 18 |
| 7.2.2 | Model Physical Connections..... | 19 |
| 7.2.3 | Model Logical Connections..... | 19 |
| 7.2.4 | Perform Requirements Gap Analysis..... | 19 |
| 7.2.5 | Develop Analysis Questions..... | 19 |
| 7.2.6 | Perform Functional Analysis..... | 19 |
| 7.2.7 | Perform Parametric Analysis..... | 19 |
| 7.3 | Analysis Document Generation..... | 19 |
| 8.0 | Findings, Observations, and NESC Recommendations | 20 |
| 8.1 | Findings..... | 20 |
| 8.2 | Observations..... | 21 |
| 8.3 | NESC Recommendations..... | 22 |
| 9.0 | Alternate Viewpoint | 23 |
| 10.0 | Other Deliverables | 23 |
| 11.0 | Lesson Learned | 23 |
| 12.0 | Recommendations for NASA Standards and Specifications | 23 |
| 13.0 | Definition of Terms | 23 |
| 14.0 | Acronym List | 25 |
| 15.0 | References | 27 |


| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 4 of 27 | |

List of Figures

| | | |
|---------------|---------------------------------------------------------------------------------------------------|----|
| Figure 4.0-1. | Systems Modeling Language (SysML) Model Scope | 8 |
| Figure 6.0-1. | Overview of Modeling and Simulation (M&S) of System Behavior at SLS/MPCV/GSDO Interfaces | 10 |
| Figure 7.2-1. | Model-based IRD/ICD Interface Review Process | 18 |
| Figure 7.3-1. | GAILA Table of Contents | 20 |

List of Tables

| | | |
|--------------|-----------------------------------------------------|----|
| Table 7.1-1. | Reference Documents for this Assessment..... | 11 |
| Table 7.1-2. | Context Documents for this Assessment | 14 |
| Table 7.1-3. | Data Sources for the SLS-MPCV-GSDO SysML Model..... | 15 |


| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 5 of 27 | |

Technical Assessment Report

1.0 Notification and Authorization

The Exploration Systems Development (ESD) Standing Review Board (SRB) requested the NASA Engineering and Safety Center (NESC) conduct an independent review of the plan developed by Ground Systems Development and Operations (GSDO) for identifying models and emulators to create a tool(s) to verify their command and control software. The NESC was requested to identify any issues or weaknesses in the GSDO plan.

The assessment was approved out-of-board on February 18, 2014. Mr. Michael L. Aguilar was assigned to lead this assessment. The primary stakeholder and requestor for this assessment is Mr. LeRoy Cain, Chair, ESD SRB.

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 6 of 27 | |

2.0 Signature Page

Submitted by:

Team Signature Page on File - 6/16/14

Mr. Michael L. Aguilar Date

Significant Contributors:

Mr. Kevin H. Bonanne Date

Mr. Jeffrey A. Favretto Date

Ms. Maddalena M. Jackson Date


Ms. Stephanie L. Jones Date

Mr. Ryan M. Mackey Date

Mr. Marc A. Sarrel Date

Ms. Kimberly A. Simpson Date

Signatories declare the findings, observations, and NESC recommendations compiled in the report are factually based from data extracted from program/project documents, contractor reports, and open literature, and/or generated from independently conducted tests, analyses, and inspections.


| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | | Page #: 7 of 27 |

3.0 Team List

| Name | Discipline | Organization |
|-------------------------------|------------------------------|--------------|
| Core Team | | |
| Michael Aguilar | NESC Lead | GSFC |
| Kimberly Simpson | Task Lead | JPL |
| Loutricia Johnson | MTSO Program Analyst | LaRC |
| Kevin Bonanne | Systems Architect | JPL |
| Jeff Favretto | Systems Engineer | JPL |
| Maddalena Jackson | Systems Architect | JPL |
| Stephanie Jones | Systems Architect | JPL |
| Ryan Mackey | Systems Engineer | JPL |
| Marc Sarrel | Systems Architect | JPL |
| Administrative Support | | |
| Melinda Meredith | Project Coordinator | LaRC/AMA |
| Linda Burgess | Planning and Control Analyst | LaRC/AMA |
| Jonay Campbell | Technical Writer | LaRC/NG |

3.1 Acknowledgements

The team would like to thank the Ground Systems Development and Operations (GSDO) Program and the Command, Control, Communications, and Range points of contact (Kirk Lougheed, Christie Best, Robert Waterman, and Patricia Nicoli) for their cooperation and for providing the wealth of reference material—essentially more than 20 design, interface, and requirements documents, including the Space Launch System-GSDO emulator and simulator bilateral exchange agreement. A very special thanks to Christie Best and her team for their quick responses to the many requests for data and clarifications related to the technical design.

| | | | |
|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| | Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 8 of 27 |

4.0 Executive Summary

On February 14, 2014, the Explorations Systems Directorate (ESD) Standing Review Board (SRB) requested an independent assessment of the Ground Systems Development and Operations (GSDO) plan for integrating models and emulators to create a tool(s) for verifying their command and control software.

The objective of this independent assessment was to provide answers to or identify where there may be gaps in addressing the following questions:

- Where do the hardware/emulators/simulators fit within the architecture?
- What functions do they verify?
- Who is building the hardware/emulators/simulators?
- When are the hardware/emulators/simulators delivered?

Previous NASA Engineering and Safety Center (NESC) assessments [refs. 1 and 2] reviewed the Space Launch System (SLS)–Multi-Purpose Crew Vehicle (MPCV)–GSDO interfaces presented in green in Figure 4.0-1. The interfaces in orange needed to be added to perform this assessment.

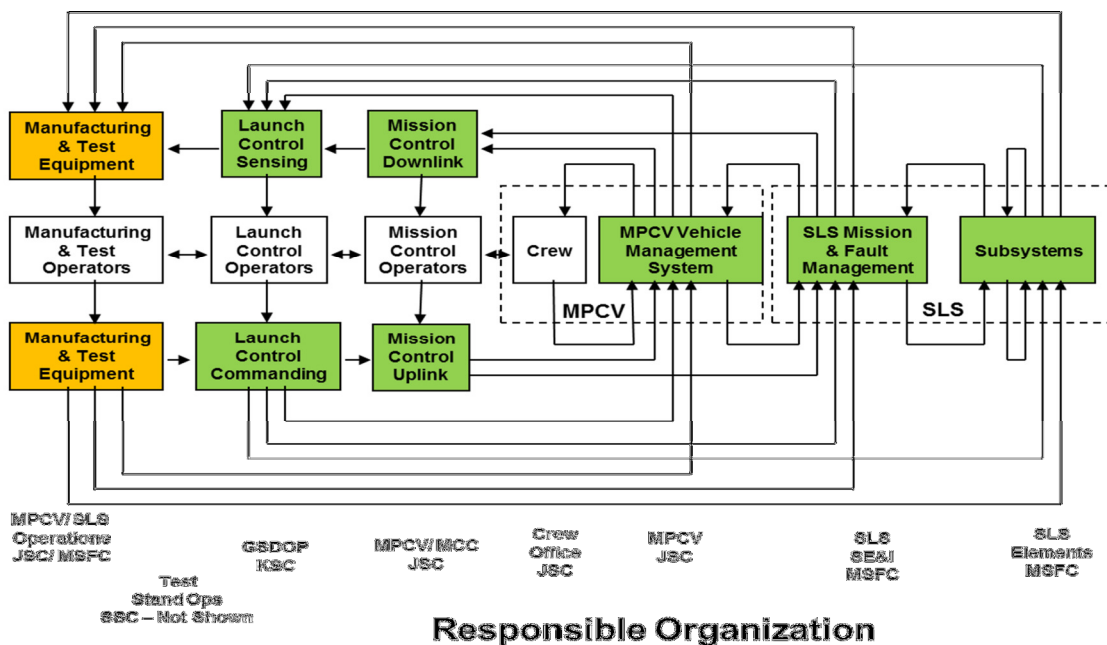



Figure 4.0-1. Systems Modeling Language (SysML) Model Scope

Results of the independent assessment (i.e., issues and weaknesses) were presented to the ESD SRB on April 8, 2014. Findings, observations, and NESC recommendations for this assessment are detailed in this report.

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | | Page #: 9 of 27 |

5.0 Assessment Plan

Major milestones for this report included:

| Milestone | Date |
|---------------------------------------------------------------------|-------------------|
| Out-of-Board Assessment Notification to the NESC Review Board (NRB) | February 18, 2014 |
| Kickoff with SLS-MPCV-GSDO Modeling Team | February 20, 2014 |
| NRB Assessment Plan Approval | February 28, 2014 |
| NRB Approval of Preliminary Stakeholder Briefing | April 4, 2014 |
| ESD SRB Presentation of Issues and Weaknesses | April 8, 2014 |


The scope of deliverables for this assessment included:

- Briefing of issues and weaknesses to the ESD SRB on April 8, 2014.
- Model views incorporating selected test environment of space hardware and test hardware for analysis.
- Operational scenarios required to be verified for the selected test environment (not completed; refer to recommendation 1).
- Findings, observations, and NESC recommendations, which are included in this report.

6.0 Problem Description, Proposed Solutions, and Risk Assessment

The length in workdays from kickoff to ESD SRB briefing was 25 days.

One benefit of model-based analysis was that the single model could be used and reused to capture physical, logical, functional, and parametric attributes. As shown in Figure 6.0-1, previous NESC assessments [refs. 1 and 2] developed a SysML model of the SLS-MPCV-GSDO interfaces for Exploration Flight Test (EFT)-1 and Exploration Mission (EM)-1. This assessment added integration and test (I&T) interfaces to this previous model.

| | | | |
|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| | Review of GSDO Tools for Verifying Command and Control Software | | Page #: 10 of 27 |

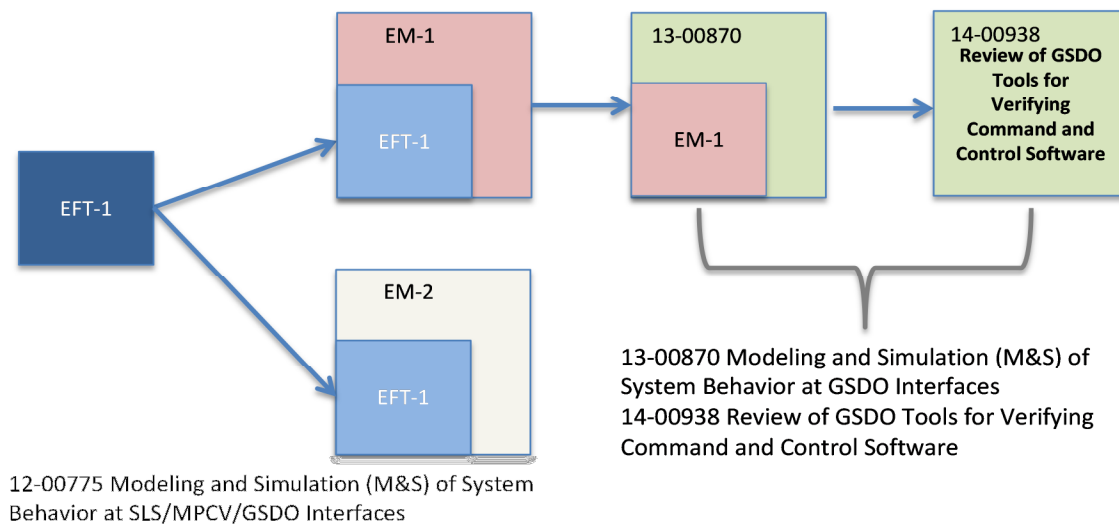


Figure 6.0-1. Overview of Modeling and Simulation (M&S) of System Behavior at SLS/MPCV/GSDO Interfaces

The same modeling team employed in the previous NESC assessments was assigned to this task, thereby minimizing any delay in tool installation and model development.


Interfaces and contacts to the in-line GSDO engineers were developed to access documentation and to take advantage of subject matter expertise. GSDO involvement was maintained as “value-added” to the in-line effort.

The Launch Control Subsystem (LCS) is being built in a series of builds, also known as evolutions. The LCS Build Plan [ref. 3] identifies the content of each build and the information sources that elaborate on that content description. The builds occur roughly every year, with some variation due to external program requirements. Development within the build is performed in a series of iterations. The following I&T environment builds were selected for this assessment due to their schedule alignment and relevance to the task objectives:

- Build 14-1: The next build in the cycle (October 2014), supporting EFT-1.
- Build 16-1: Has mature content to represent an EM-1 flight environment.

7.0 Data Analysis

A list of the products incorporated into the assessment can be found in the reference documents (see Table 7.1-1). The model used to generate this document reflects a generic GSDO configuration appropriate for the scope of this assessment, including operational support, and was not limited to Customer Avionics Interface Development and Analysis (CAIDA)-specific testing.

| | | | |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------|------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: | Version: |
| | | NESC-RP-14-00938 | 1.0 |
| Title: | | Page #: | |
| Review of GSDO Tools for Verifying Command and Control Software | | 11 of 27 | |

The following test facilities were identified:

- GSDO Multipurpose Processing Facility
- GSDO Firing Room (FR)-1
- GSDO FR-3
- GSDO CAIDA Laboratory
- MPCV Integration Test Laboratory (ITL) (i.e., integrated mission simulations using MPCV, SLS, and Interim Cryogenic Propulsion System (ICPS) emulators/simulators)
- MPCV Operations and Checkout (O&C) Facility
- MPCV Mission Control Center (MCC)
- SLS System Integration Laboratory (SIL) (i.e., integration testing utilizing SLS high-fidelity emulators and flight software, including ICPS integration)

Where applicable to the assessment, internal and external test interfaces and available emulators and simulators are captured in the GSDO Avionics Integration Laboratories Assessment (GAILA) architecture within the model.

7.1 Source Documents for this Assessment

The documents listed in Table 7.1-1 were reviewed and included in the assessment model development. At the close of this assessment, the SLS-MPCV-GSDO SysML model being used contained applicable details from over 50 documents.

The SLS Real-Time Simulation to GSDO Real-Time Simulation Interface Control Document baseline (draft), dated March 4, 2014, could not be reviewed within the timeframe for this assessment.

Table 7.1-1. Reference Documents for this Assessment

| No. | Document ID | Document Title | Description | Date |
|-----|-----------------|--------------------------------------------------|------------------------------------------------------------------------------------------|------------|
| 1 | C3R E2ECC LX-D2 | Risk 11803 Task ID 41897 Risk Mitigation | Avionics/Software Integration Team Risk Mitigation task description, April 2013 | 4/30/2013 |
| 2 | CAIDA SRR | CAIDA Lab System Requirements Review (SRR) | CAIDA SRR presentation | 10/29/2013 |



NASA Engineering and Safety Center Technical Assessment Report

Document #:
**NESC-RP-
14-00938**


Version:
1.0

Title:

Review of GSDO Tools for Verifying Command and Control Software


Page #:
12 of 27

| No. | Document ID | Document Title | Description | Date |
|-----|----------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 3 | EFT-1 GSADD | EFT-1 Ground System Architecture Description Document | Model of EFT-1 ground system, including O&C–Denver ITL interfaces in support of assembly, test, and launch operations (ATLO) and launch control center (LCC) flight-following design | 3/11/2014 |
| 4 | EFT-1 LCS Interfaces | EFT-1 Telemetry to LCS Connectivity Diagram | Microsoft® Visio® diagram of FR-1 connectivity to CAIDA in FR-3 | 8/1/2013 |
| 5 | ESD 10019 | Exploration Systems Integration Avionics and Software Integration Plan | Draft definition of the multi-program approach to key avionics and software discipline areas | 2014 |
| 6 | GSDO PDR | GSDO Preliminary Design Review (PDR) Kickoff Presentation | GSDO PDR kickoff presentation | 1/15/2014 |
| 7 | GSDO SADD | GSDO and Spaceport Command and Control System (SCCS) Amalgamated Description Document (SADD) | Model of GSDO ground system architecture, including Multi-Purpose Processing Facility (MPPF), Vehicle Assembly Building (VAB), LCC, and Space Launch Complex (SLC)-39B configurations in support of integration testing and command, control, and communications data flows | 3/11/2014 |
| 8 | K0000112994-PLN | LCS BUILD PLAN | LCS Build Plan, Revision A | 7/5/2013 |
| 9 | K0000112995-SPC | SCCS Project SDD Volume 1 | System Design Document (SDD) for the SCCS, Volume 1, Revision A | 8/1/2013 |
| 10 | K0000118139-SPC | SCCS Project SDD Volume 4 | SDD Command and Control System, Volume 4 Revision A | 8/2/2013 |
| 11 | K0000147171-GEN | CAIDA Lab Concept of Operations (ConOps) - Basic Revision | Draft CAIDA ConOps document (unreleased), April 2013 | 4/30/2013 |

| | | | |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| | | Review of GSDO Tools for Verifying Command and Control Software | |

| No. | Document ID | Document Title | Description | Date |
|-----|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 12 | KSC 9.1.6 ODN TOP | KSC 9.1.6 Onboard Data Network (ODN) Topology Diagram | Kennedy Space Center (KSC) ODN Topology – Honeywell Virtual Test Bench (HVTB) wiring diagram | |
| 13 | March 2014 IAS ITT TIM Materials | ConOps for March 2014 Information Architecture System (IAS) International Telephone and Telegraph (ITT) Technical Interchange Meeting (TIM) | Testing ConOps TIM Notes, March 2014 | 3/2014 |
| 14 | P2P-00003 | SLS-GSDO Bilateral Exchange Agreement (BEA) in support of Program-to-Program Delivery of Models and Emulators | Document deliveries of models and emulators between GSDO and SLS via BEA deliverables matrix | Baseline April 2013 |
| 15 | TT_7_CAIDA_SRB | CAIDA SRB Tabletop Agenda | Presentation on the status of the CAIDA facility and its interaction with SLS Core, ICPS, and Orion* (including European Space Agency (ESA) Service Module) | 2/12/2014 |

* Within some of the documentation, primarily Lockheed-Martin sources, the term Orion was used instead of the term MPCV. MPCV and Orion are used interchangeably to refer to the MPCV Program side of an interface (e.g., MPCV – GSDO IRD, MPCV – SLS ICD, etc.)—both are valid product naming conventions with the MPCV Program.


| | | | |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------|-----------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: | Version: |
| | | NESC-RP-14-00938 | 1.0 |
| Title: | | | Page #: |
| Review of GSDO Tools for Verifying Command and Control Software | | | 14 of 27 |

The documents listed in Table 7.1-2 were reviewed but due to their scope were not used in the development of this model.

Table 7.1-2. Context Documents for this Assessment

| No. | Document ID | Document Title | Description | Date |
|-----|-----------------------------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| 1 | CAIDA Access Control Policy | CAIDA Lab Access Control Policy | Document describing the guidelines, process, and procedures for which user access to the CAIDA system will be managed. April 1, 2014, from Christie Best | 4/1/2014 |
| 2 | CAIDA IT CM Process | CAIDA Lab Information Technology (IT) Configuration Management (CM) Process | Document describing process for handling changes to hardware, software, and IT security settings; April 1, 2014, from Christie Best | 4/1/2014 |
| 3 | CAIDA VMat | CAIDA Validation Matrix | CAIDA requirements and description of functionality | 1/9/2014 |
| 4 | GSDO-PLN-1078 | GSDO Program: EFT-1 Mission Implementation Plan | Supporting material related to EFT-1 flight following plans and design | CR 03/14 |
| 5 | MPCV OPSR | EM-1 Orion* ITL | Layout diagram of virtual test bed (VTB), notations of SLS and ICPS Engineering Modules, and identification of electrical ground support equipment (EGSE) that connects Integrated Robotics Facility (IRF) building to KSC via NASA Integrated Services Network (NISN) | 2/27/2014 |

* Within some of the documentation, primarily Lockheed-Martin sources, the term *Orion* was used instead of the term *MPCV*. MPCV and Orion are used interchangeably to refer to the MPCV Program side of an interface (e.g., MPCV – GSDO IRD, MPCV – SLS ICD, etc.)—both are valid product naming conventions with the MPCV Program.

| | | | |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| | | Review of GSDO Tools for Verifying Command and Control Software | |

The documents listed in Table 7.1-3 were reviewed and included in the SysML model development of the SLS-MPCV-GSDO interfaces generated in previous NESC assessments [refs. 1 and 2].

Table 7.1-3. Data Sources for the SLS-MPCV-GSDO SysML Model

| # | Name | Documentation |
|---------------------------------|-------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SLS-MPCV_GSDO Interfaces | | |
| 1 | Task Description 12-00775_MPCV-SLS Modeling | Description, participants, etc., of MPCV-SLS modeling task. |
| 2 | ESD_ConOps_Sept_2011 | The ConOps is a companion document to the ESD Requirements Document. It describes a bounding set of missions and roles of systems within those missions to provide scope for interpretation and implementation guidance of the controlled requirements. |
| 3 | SLS-PLAN-020_SLSP_Concept_of_Operations_Con_Ops | The SLS ConOps Document describes the system concept, operational characteristics, and uses of the SLS, and how it is envisioned to provide cargo and/or crew launch capability for space exploration and science, and, if required, support commercial missions. |
| 4 | IMA_Report_Post-SRR_Release_2-29-12_13 | The purpose of the Integrated Mission Analysis (IMA) Report is to document the results of a joint ESD-Program analysis of the ESD ConOps (ESD 10012). |
| 5 | SLS_Capabilities_14 | Part of the IMA |
| 6 | MPCV_Capabilities_14 | Part of the IMA |
| 7 | Master_Capabilities_List | Part of the IMA |
| 8 | EM-1 Model | On server sscac-cmr:17011. |
| 9 | ESMD-HEC.Reqt-6.2011_REDLINE% 2009-16-11[1] | This document focuses on functional requirements driven by architectural analysis. The ESD Requirements Document captures requirements controlled by the Human Exploration and Operations Mission Directorate for SLS, MPCV, and GSDO. Requirements will be levied against future programs as the new program elements transition from architecture studies into program formulation. |
| 10 | Engine_Out_Dukeman | Presentation of Rid 0063: Core Engine Out Capability. |
| 11 | EFT-1 Model | On server sscac-cmr:17011. |
| 12 | MPCV 70028 GS IRD Baseline - 2012_06_25 | The purpose of this Interface Requirements Document (IRD) is to define the detailed interface requirements and verification methods for interfaces between Orion* and GSDO. |
| 13 | MPCV 70026 SLS IRD_Baseline_FINAL | This IRD defines the detailed interface requirements and verification methods for interfaces between Orion* and SLS. All requirements in this document will apply to the SLS vehicle (i.e., core and ICPS) unless explicitly stated otherwise. |



NASA Engineering and Safety Center Technical Assessment Report

Document #:
**NESC-RP-
14-00938**

Version:
1.0

Title:

Review of GSDO Tools for Verifying Command and Control Software

Page #:
16 of 27

| # | Name | Documentation |
|-------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 14 | MPCV 70029 MS IRD Baseline - 06132012 | This IRD defines the detailed interface requirements and verification requirements for MPCV Program interfaces between Orion* and Mission Systems. |
| GSDO Project Documents | | |
| 1 | GSDO SCCS to Advanced Ground Systems Maintenance Interface Design Document (IDD) | Describes the interfaces between SCCS and Advanced Ground System and Maintenance (AGSM). |
| 2 | SCCS SDD: Volume 1 | Describes SCCS, which includes LCS and KSC Ground Control System (KGCS). Captured from .pdf on KSC Design Data Management System (KDDMS), 26 September 2013. |
| 3 | SCCS SDD Vol 2 | Traceability table for the SCCS SDD. |
| 4 | SCCS_SDD_Vol5_ hack.pdf | Contains SCCS use cases |
| 5 | MPCV 72548 MS to GSDO ICD | MPCV Mission Systems to GSDO Interface Control Document (ICD), Baseline draft, dated May 2013. |
| 6 | GSDO-ACO-1010.pdf | GSDO Architecture and ConOps, dated 29 April 2013. Sourced from GSDO SharePoint® repository. |
| 7 | C3R-3008_Rev._ Baseline.pdf | 100 percent (baseline) version of Command, Control, Communications, and Range (C3R) ConOps, dated 24 June 2013. |
| | MPCV 70028 GS IRD_Rev A_Final_ 19Dec2012.pdf | Revision A MPCV-GSDO IRD, dated 19 December 2012. Sourced from the MPCV Program CM Library. |
| 8 | SLS-ICD-052-5 SLSP to GSDO ICD V5 Software Peer Review Consolidated Comments 121108.docx | 60 percent draft version of SLS to GSDO ICD Volume 5, dated 25 October 2012. |
| 9 | KGCS_ICD_doc.pdf | ICD for KGCS. |
| 10 | KGCS_Conops.pdf | Overall ConOps for KGCS only. Official but dates back to 2010. |
| 11 | CTU_vs_LCS_V2.pdf | Diagram of LCC to MPCV communications options (3 pages). |
| 12 | CEV-T-029930 Orion* to GSDO ICD Volume 2 | Orion* to GSDO Software Interfaces, draft, dated 5 December 2013. |



NASA Engineering and Safety Center Technical Assessment Report

Document #:
**NESC-RP-
14-00938**

Version:
1.0


Title:

Review of GSDO Tools for Verifying Command and Control Software

Page #:
17 of 27

| # | Name | Documentation |
|------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13 | MPCV 70054 MPCV: MS to GSDO IRD | Revision A, dated 6 March 2013. |
| C3R Documents | | |
| 1 | C3R Integrated Program Review (IPR), Complete | Contains high-level C3R requirements, interdependencies, architecture of communications, and GSDO software. Dated 24 June 2013. |
| 2 | C3R Integrated Product Team (IPT) Overview and input to Offline Processing and Infrastructure (OPI) and Vehicle Integration and Launch (VIL) IPR | Lengthy discussion of C3R including software, launch control operations, and communications with SLS when on ground. |
| 3 | C3R Software Architecture PowerPoint® Presentation | High-level architecture overview that described all the elements of the command and control system and how they interact. Includes identification of commercial off-the-shelf software, GSDO developed wrappers, and middleware. |
| 4 | ProjectPlan.pdf | Nine-page summary of the C3R architecture, with some risks, team members, and abbreviated project schedule. |
| 4 | C3R Product Architecture_screencaps.pptx | Screen captures from the HTML-based overview of the C3R Product Architecture, dated 23 May 2013. |
| Supporting Documents from Other Sources | | |
| 1 | Integrated Communications and Network (ICAN) Point of Departure | Version 4, dated 6 May 2013. |
| 2 | EM-1 Integrated Communication Summary | PowerPoint® presentation, dated 5 December 2013. |
| 3 | MPCV to LCC Communications Trade | Diagram of communication options, currently under study, 15 August 2013. |

* Within some of the documentation, primarily Lockheed-Martin sources, the term *Orion* was used instead of the term *MPCV*. MPCV and Orion are used interchangeably to refer to the MPCV Program side of an interface (e.g., MPCV – GSDO IRD, MPCV – SLS ICD, etc.)—both are valid product naming conventions with the MPCV Program.

| | | | |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------|-------------------------|------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: | Version: |
| | | NESC-RP-14-00938 | 1.0 |
| Title: | | Page #: | |
| Review of GSDO Tools for Verifying Command and Control Software | | 18 of 27 | |

7.2 Review Process

The process for this assessment was similar, if not identical, to the process used on previous NESC assessments [refs. 1 and 2]. Data were collected from available sources. The physical and logical interfaces were defined within the model. Analysis was performed using the SysML model (see Figure 7.2-1).

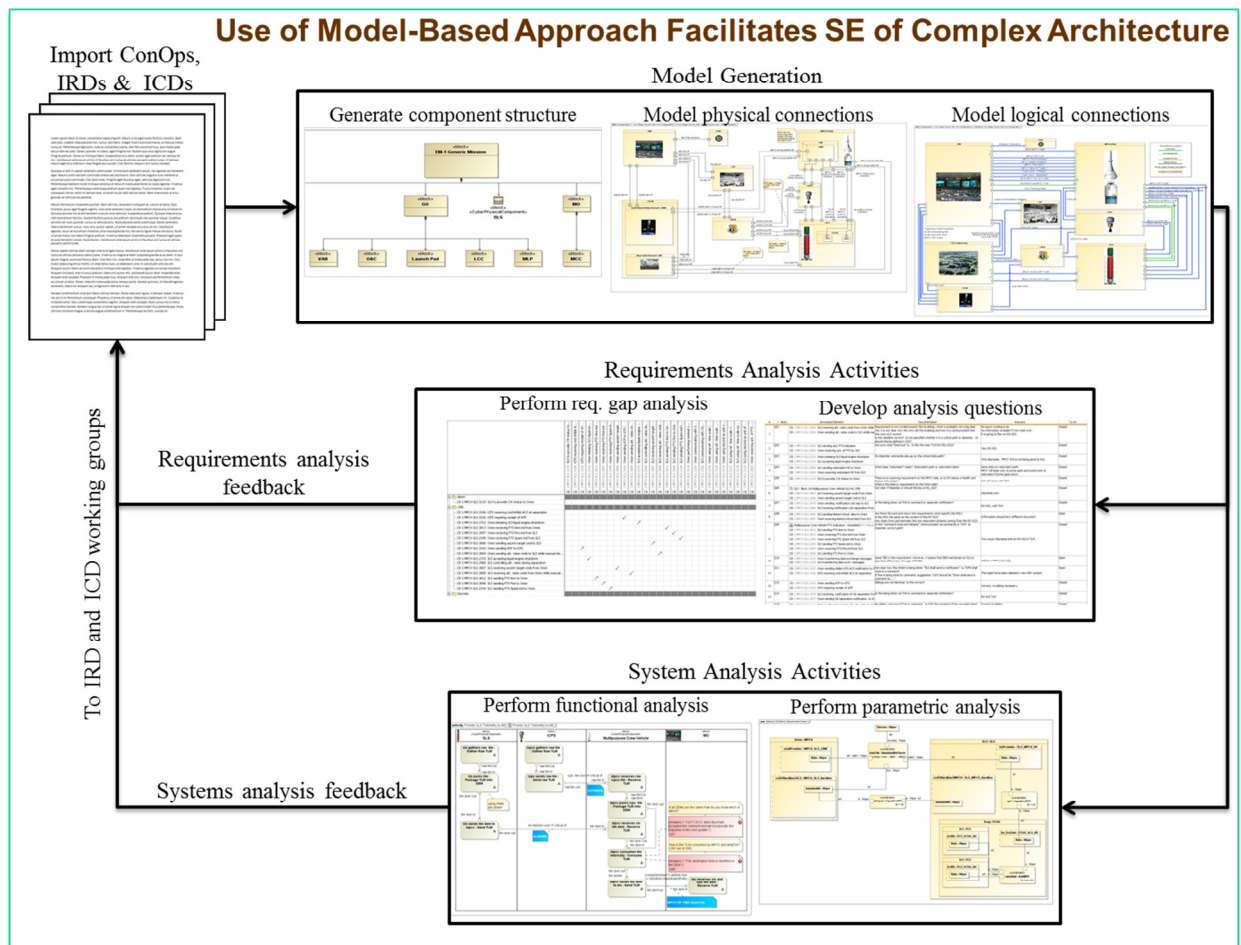



Figure 7.2-1. Model-based IRD/ICD Interface Review Process

All issues and weaknesses were reported to the document owners in a manner accepted by the GSDO stakeholders.

7.2.1 Generate Component Structure

The system components are identified and organized. Components can be locations, buildings, structures, components, etc. This provides the “structure” of the model.

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 19 of 27 | |

7.2.2 Model Physical Connections

Physical connections are the physical interfaces between the components. Physical connections can be trunk lines, Internet, radio links, ducts, etc.

7.2.3 Model Logical Connections

Logical connections identify the type of information or data carried over the physical connections. Logical connections can be voice, telemetry, commands, controls, power, etc.

7.2.4 Perform Requirements Gap Analysis

Missing requirements and inconsistent requirements can be addressed as the model matures. The modeling tool itself produces reports of missing physical and logical connections, and reports of inconsistencies in the connections. These reports can identify the areas of the model that need correction or more complete detail.

7.2.5 Develop Analysis Questions

This assessment provided reports of issues to the in-line experts based on the model analysis. The issues were addressed within the in-line documents and the model itself. Traces of the questions and responses were maintained within the model itself.

7.2.6 Perform Functional Analysis

A minimum of functional analysis was performed for this assessment. Functional analysis requires operational scenarios to be detailed or developed from users and operators. This detail was unavailable to this assessment.


7.2.7 Perform Parametric Analysis

Functional analysis can further be quantified using parametric assignments to attributes within scenarios. Scenarios can be instrumented with values representing execution time, loading, throughput, bandwidth, etc. This level of detail was unavailable to this assessment.

7.3 Analysis Document Generation

All text, tables, and illustrations in the GAILA report were extracted and formatted from the SysML model repository. Figure 7.3-1 indicates the information that was generated. This generated GAILA report contains sensitive but unclassified material and is available from the NESC upon appropriate request.¹

¹ This document can be obtained by submitting a request to the NESC at:
<http://www.nasa.gov/offices/nesc/home/index.html>

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 20 of 27 | |

| |
|-------------------------------------------------------|
| Section 1. Introduction |
| 1.1. Reference Documents |
| 1.2. Context Documents |
| Section 2. Forward Work and Known Issues |
| Section 3. Builds |
| 3.1. Build 14-1 Non-Hazardous Operations C&C |
| 3.1.1. Logical Data Level |
| 3.1.2. Physical Data Level |
| 3.2. Build 16-1 Operational Spaceport C&C |
| 3.2.1. Logical Data Level |
| 3.2.2. Physical Data Level |
| Appendix A. Acronyms and Abbreviations |
| Appendix B. Unknowns and Assumptions |
| B.1. Unknowns |
| B.2. Resolved Unknowns |
| B.3. Assumptions |


Figure 7.3-1. GAILA Table of Contents

8.0 Findings, Observations, and NESC Recommendations

8.1 Findings

The following findings were identified:


- F-1.** What the GSDO Program team has implemented and plans to implement appears to be sound in terms of physical entities and interfaces; the architecture documents plans to supply an I&T capability to many stakeholders. However, such a large set of stakeholders (i.e., SLS, MPCV, GSDO, and ESD) will drive the configuration in multiple directions, with the quantity and diversity of use taxing the system.
- F-2.** The GSDO Program team has done a good job of identifying what is going to be built but did not produce additional detail regarding how it will be built. Documentation describing the interfaces between CAIDA and other test facilities was not located. The cross-program integrated schedule did not provide sufficient detail in the plans for all program emulators and simulators.
- F-3.** The documentation, listed in Table 7.1-1, was missing details regarding expectations of resource utilization (e.g., the number of available emulators/simulators required to run all tests; staffing and required expertise/skills to operate CAIDA; etc.).
- F-4.** Risk is introduced in integration, testing, and schedule activities because important BEAs have not been completed.

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 21 of 27 | |

- F-5.** Requirements on MPCV and SLS engineering resources in support of CAIDA operations are not detailed in any of the documents listed in Table 7.1-1.
- F-6.** The Exploration Systems Integration Avionics and Software Integration Plan was used as a reference to understand the flow-down of expectations on cross-program avionics and software integration, but it did not provide any additional detail relevant to the integration of GSDO's emulators and simulators.
- F-7.** Deriving cross-system software functionality proved difficult. A set of CAIDA requirements does exist, but the requirements were sometimes too low level. This can be problematic when there are no functional requirements or traceability to the problems addressed by lower level requirements. In some cases, the rationale for a requirement reads as though it should be the written requirement.
- F-8.** The tools themselves were capable when accessed in a distributed manner; however, access to the model for distributed development and review was hindered by Center server restrictions and time constraints such that no additional users were added.
- F-9.** Use of a third-party tool set to generate final formatted documentation from the model was successful. The modeling tool provides the capabilities for viewing the model, but formatted documentation was preferred by the in-line stakeholders.

8.2 Observations

- O-1.** The assessment team was unable to determine loading of test beds at this point. PDR is early to have detailed specifics, but a general sense of overall resource loading and stakeholder requirements on test beds should be known.
- O-2.** It is not clear how GSDO emulators are acceptance tested prior to delivery to SLS.
- O-3.** Requirements on MPCV and SLS engineering resources in support of CAIDA operations are unclear.
- O-4.** The coordination of simulations between SLS and MPCV within CAIDA is unknown. The documentation seems to reflect that there will be two halves of CAIDA developed (i.e., one to support MPCV and one to support SLS), but it is not clear how the two will integrate in support of simulation of MPCV-SLS interactions.
- O-5.** When polled for questions, the engineers understand the design and what is to be developed, but documentation does not always reflect their understanding and can be unclear and inconsistent.
- O-6.** The support from the in-line GSDO experts was greatly appreciated.
- O-7.** This assessment leveraged an existing SLS-MPCV-GSDO interface model by adding test facilities and interfaces. Using model-based analysis, this assessment of the GSDO I&T environments was accomplished in 25 work days.

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 22 of 27 | |

8.3 NESC Recommendations

The following NESC recommendations are directed to the GSDO Program.

- R-1.** Specify the minimum CAIDA use cases to define the testing control and operations prior to 45-percent review to identify inherent risks related to over-subscription or complexity. *(F-1)*

The following are examples of recommended use cases:

- LCS verification and validation (V&V).
- Emulator V&V (e.g., HVTB, ground support equipment (GSE)).
- Consistency checking process for verification of emulators supplied by GSDO to other Centers (i.e., GSDO Advanced Hardware LCS Emulator (GAHLE), GSDO Lightweight All-Digital Emulator (GLADE)) prior to use in formal testing.
- SHADE acceptance testing.
- Remote access path to external MPCV and SLS test beds.
- CAIDA to test FR-1.
- Use of emulators/simulators in support of training.
- Data management paths and resources (e.g., data recording and playback processes in support of testing or troubleshooting).
- CAIDA validation, CM, diagnostics, and regression testing.


- R-2.** Identify/generate the integration schedule to ensure GSDO receivables and deliverables align in content and schedule. *(F-2)*

- R-3.** Develop CADIA I&T environment requirements. *(O-1)*

The following are examples of requirements areas of interest:

- Reference verification activities requiring CAIDA.
- External requirements verified using CAIDA.
- Time required to run external stakeholder's verification activities.
- "Subsystem" assumptions on CAIDA use (e.g., physical access, data security, software simulators, electrical needs, power, heating, cooling, training, support, spares, downtime allowed, maintenance overhead, interfaces within the facility, and floor space and volume requirements).

- R-4.** Determine and track the status of the BEAs between the programs. The lack of formal BEAs is a risk to schedule and effort during planning, programming, budgeting, and execution (PPBE) cycles. *(F-4)*

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 23 of 27 | |

R-5. Document functional requirements as use cases to quantify CAIDA’s capabilities. The development and documentation of ConOps use cases is needed to define CAIDA’s required functions. The development and documentation of V&V use cases is necessary to define use as a reliable testbed for GSDO needs (e.g., V&V, training activities, etc.). *(F-7)*

R-6. Analyze the differences between the flight vehicle on the pad and the I&T environment. The development of I&T facilities has primarily been a bottom-up development process. A comparison between the flight vehicle on the pad and the I&T environment would determine differences and residual risk, as well as determine how close the I&T facility is to the “test like you fly” concept. *(F-7)*

9.0 Alternate Viewpoint

There were no alternate viewpoints identified during the course of this assessment by the NESC team or the NRB quorum.

10.0 Other Deliverables

- Generated model report: GAILA is a separate .pdf document generated from the model data. It was the basis for the presentation to the ESD SRB.
- SLS-MPCV-GSDO-I&T SysML model: The model is maintained on a server at Jet Propulsion Laboratory (JPL). It is currently supported by JPL for an in-line SLS task.

11.0 Lesson Learned

No lessons learned were identified as a result of this assessment.


12.0 Recommendations for NASA Standards and Specifications

No recommendations for NASA standards and specifications were identified as a result of this assessment.


13.0 Definition of Terms

Corrective Actions Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.

Finding A relevant factual conclusion and/or issue that is within the assessment scope and that the team has rigorously based on data from their

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 24 of 27 | |


| | |
|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| independent analyses, tests, inspections, and/or reviews of technical documentation. | |
| Functional Model | A structured representation of the functions (i.e., activities, actions, processes, and operations) within the modeled system or subject area. |
| Lessons Learned | Knowledge, understanding, or conclusive insight gained by experience that may benefit other current or future NASA programs and projects. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. |
| Logical Model | A graphical representation of the flow of data through an information system, modeling its <i>process</i> aspects—often a preliminary step used to create an overview of the system that can be elaborated upon later. A logical model shows what kind of information will be input to and output from the system, where the data will come from and go to, and where the data will be stored. It does not show information about the timing of processes or information about whether processes will operate in sequence or in parallel. |
| Observation | A noteworthy fact, issue, and/or risk that may not be directly within the assessment scope but could generate a separate issue or concern if not addressed. Alternatively, an observation can be a positive acknowledgement of a Center/Program/Project/Organization’s operational structure, tools, and/or support provided. |
| Parametric Model | A set of mathematical equations built into the model to perform automated data analysis in a reliable manner. These may be standard equations from reference books, proprietary equations developed by consultants or vendors, or some combination of the two. |
| Physical Model | Shows how the system is implemented, at the moment or how the designer intends it to be in the future. |
| Problem | The subject of the independent technical assessment. |
| Proximate Cause | The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome. |
| Recommendation | A proposed measurable stakeholder action directly supported by specific Finding(s) and/or Observation(s) that will correct or mitigate an identified issue or risk. |

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 25 of 27 | |


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| Root Cause | One of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome. |
| Supporting Narrative | A paragraph, or section, in an NESC final report that provides the detailed explanation of a succinctly worded finding or observation. For example, the logical deduction that led to a finding or observation; descriptions of assumptions, exceptions, clarifications, and boundary conditions. Avoid squeezing all of this information into a finding or observation |
| SysML | A graphical modeling language supporting the specification, analysis, design, and V&V of systems that include hardware, software, data, personnel, procedures, and facilities. |
| Use Case | A list of steps, typically defining interactions between an actor and a system, to achieve a specific goal. The actor can be a human or an external system. In systems engineering, use cases are used at a higher level than within software engineering, often representing missions or stakeholder goals. The detailed requirements may then be captured in SysML or as contractual statements. |

14.0 Acronym List

| | |
|--------|------------------------------------------------------|
| AGSM | Advanced Ground System and Maintenance |
| AMA | Analytical Mechanics Associates |
| ATLO | Assembly, Test, and Launch Operations |
| BEA | Bilateral Exchange Agreement |
| C3R | Command, Control, Communications, and Range |
| CAIDA | Customer Avionics Interface Development and Analysis |
| CM | Configuration Management |
| ConOps | Concept of Operations |
| EFT | Exploration Flight Test |
| EGSE | Electrical Ground Support Equipment |
| EM | Exploration Mission |
| ESA | European Space Agency |
| ESD | Exploration Systems Development |
| FR | Firing Room |
| GAHLE | GSDO Advanced Hardware LCS Emulator |
| GAILA | GSDO Avionics Integration Laboratories Assessment |
| GLADE | GSDO Lightweight All-Digital Emulator |
| GSADD | Ground System Architecture Description Document |

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|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP- 14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 26 of 27 | |

| | |
|-------|----------------------------------------------|
| GSDO | Ground Systems Development and Operations |
| GSE | Ground Support Equipment |
| GSFC | Goddard Space Flight Center |
| HVTB | Honeywell Virtual Test Bench |
| I&T | Integration and Test |
| IAS | Information Architecture System |
| ICAN | Integrated Communications and Network |
| ICD | Interface Control Document |
| ICPS | Interim Cryogenic Propulsion System |
| IDD | Interface Design Document |
| IMA | Integrated Mission Analysis |
| IPR | Integrated Program Review |
| IPT | Integrated Product Team |
| IRD | Interface Requirements Document |
| IRF | Integrated Robotics Facility |
| IT | Information Technology |
| ITL | Integration Test Lab |
| ITT | International Telephone and Telegraph |
| JPL | Jet Propulsion Laboratory |
| KDDMS | KSC Design Data Management System |
| KGCS | Kennedy Ground Control System |
| KSC | Kennedy Space Center |
| LaRC | Langley Research Center |
| LCC | Launch Control Center |
| LCS | Launch Control Subsystem |
| M&S | Modeling and Simulation |
| MCC | Mission Control Center |
| MPCV | Multi-Purpose Crew Vehicle |
| MPPF | Multi-Purpose Processing Facility |
| MTSO | Management and Technical Support Office |
| NESC | NASA Engineering and Safety Center |
| NG | Northrop Grumman |
| NISN | NASA Integrated Services Network |
| NRB | NESC Review Board |
| O&C | Operations & Checkout |
| ODN | Onboard Data Network |
| OPI | Offline Processing and Infrastructure |
| PPBE | Planning Programming Budgeting and Execution |
| PDR | Preliminary Design Review |
| SADD | SCCS Amalgamated Description Document |
| SCCS | Spaceport Command and Control System |

| | | | |
|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------|------------------------|
|  | NASA Engineering and Safety Center Technical Assessment Report | Document #: NESC-RP-14-00938 | Version: 1.0 |
| Title: Review of GSDO Tools for Verifying Command and Control Software | | Page #: 27 of 27 | |

| | |
|-------|--------------------------------|
| SDD | System Design Document |
| SIL | System Integration Laboratory |
| SLC | Space Launch Complex |
| SLS | Space Launch System |
| SRB | Standing Review Board |
| SRR | System Requirements Review |
| SysML | Systems Modeling Language |
| TIM | Technical Interchange Meeting |
| V&V | Verification and Validation |
| VAB | Vehicle Assembly Building |
| VIL | Vehicle Integration and Launch |
| VTB | Virtual Test Bed |

15.0 References

1. “Modeling and Simulation of System Behavior at SLS, MPCV, and GSDO Interfaces,” NESC Assessment Report NESC-RP-12-00775, publication date TBD.
2. “Modeling and Simulation of System Behavior at GSDO Interfaces,” NESC Assessment Report NESC-RP-13-00870, publication date TBD.
3. “LCS Build Plan,” Document No. K0000112994-PLN, Revision A, July 5, 2013.

REPORT DOCUMENTATION PAGE

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| 14. ABSTRACT The Exploration Systems Development (ESD) Standing Review Board (SRB) requested the NASA Engineering and Safety Center (NESC) conduct an independent review of the plan developed by Ground Systems Development and Operations (GSDO) for identifying models and emulators to create a tool(s) to verify their command and control software. The NESC was requested to identify any issues or weaknesses in the GSDO plan. This document contains the outcome of the NESC review. | | | | | |
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