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
Langley Research Center, Hampton, Virginia

Kevin H. Bonanne, Jeffrey A. Favretto, Maddalena M. Jackson, Stephanie L. Jones,
Ryan M. Mackey, Marc A. Sarrel, and Kimberly A. Simpson
Jet Propulsion Laboratory, Pasadena, California

June 2014

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NASA Aeronautics and Space Database and its public interface, the NASA Technical Report Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counterpart of peer-reviewed formal professional papers, but having less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at *http://www.sti.nasa.gov*

- E-mail your question to help@sti.nasa.gov

- Fax your question to the NASA STI Information Desk at 443-757-5803

- Phone the NASA STI Information Desk at 443-757-5802

- Write to:
  STI Information Desk
  NASA Center for AeroSpace Information
  7115 Standard Drive
  Hanover, MD 21076-1320

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
Langley Research Center, Hampton, Virginia

Kevin H. Bonanne, Jeffrey A. Favretto, Maddalena M. Jackson, Stephanie L. Jones,
Ryan M. Mackey, Marc A. Sarrel, and Kimberly A. Simpson
Jet Propulsion Laboratory, Pasadena, California

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

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.

Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320
443-757-5802

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

May 1, 2014

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:	*Original Signature on File (DS)*	*5/19/14*
	Acting NESC Director	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

Table of Contents

Technical Assessment Report

List of Figures

List of Tables

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.

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.

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.

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.

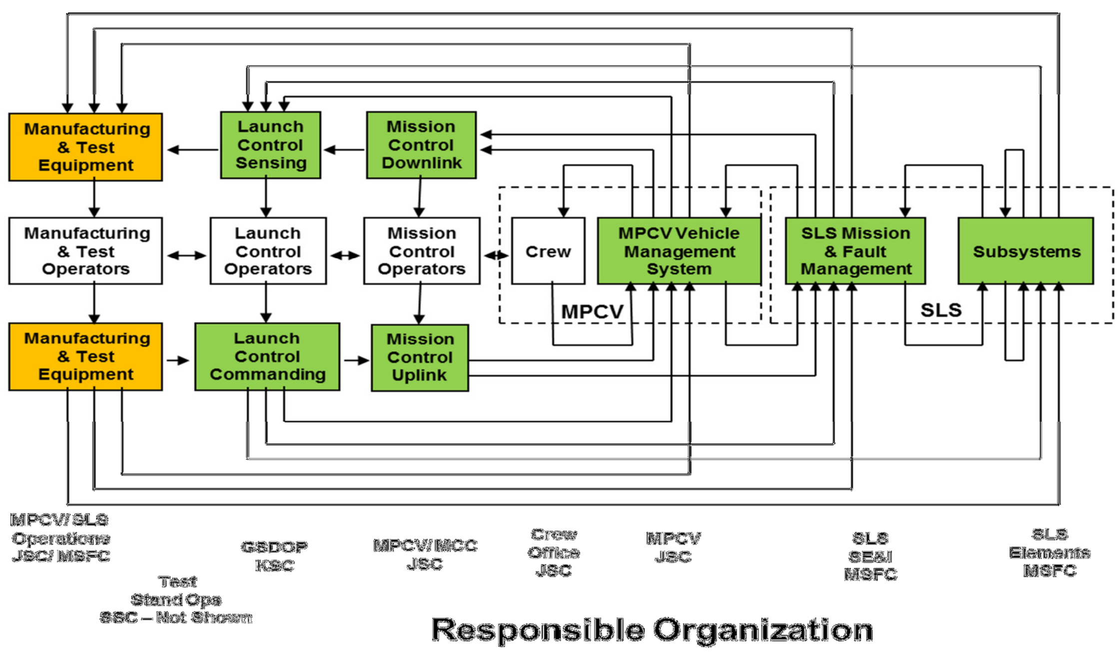

Figure 4.0-1. Systems Modeling Language (SysML) Model Scope

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.

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.

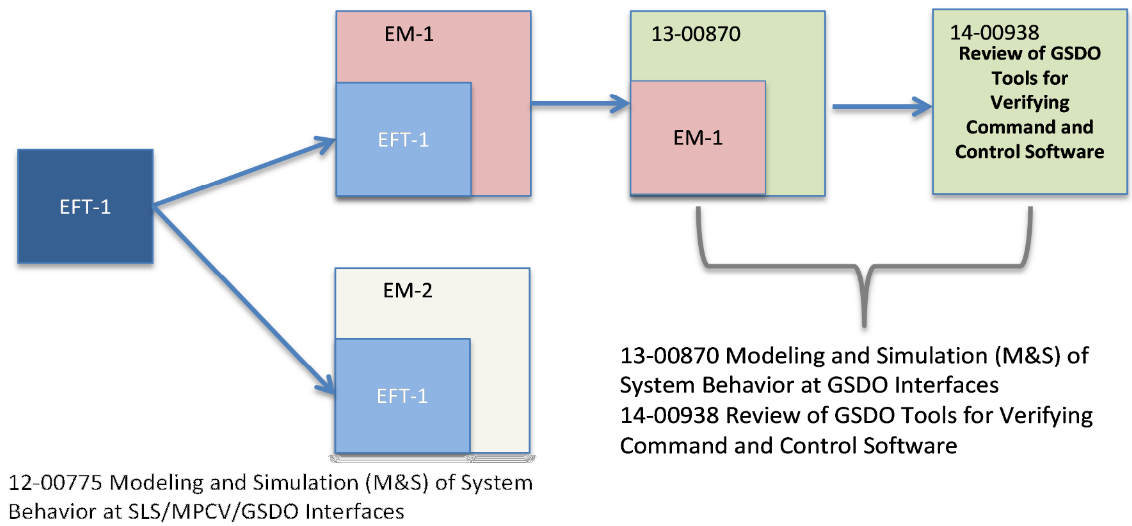

Figure 6.0-1. Overview of Modeling and Simulation (M&S) of System Behavior at SLS/MPCV/GSDO Interfaces

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.

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

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

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.

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.

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 sscae-cmr:17011.
9	ESMD-HEC.Reqt-6.2011_REDLINES%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 sscae-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.

#	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.

#	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.

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).

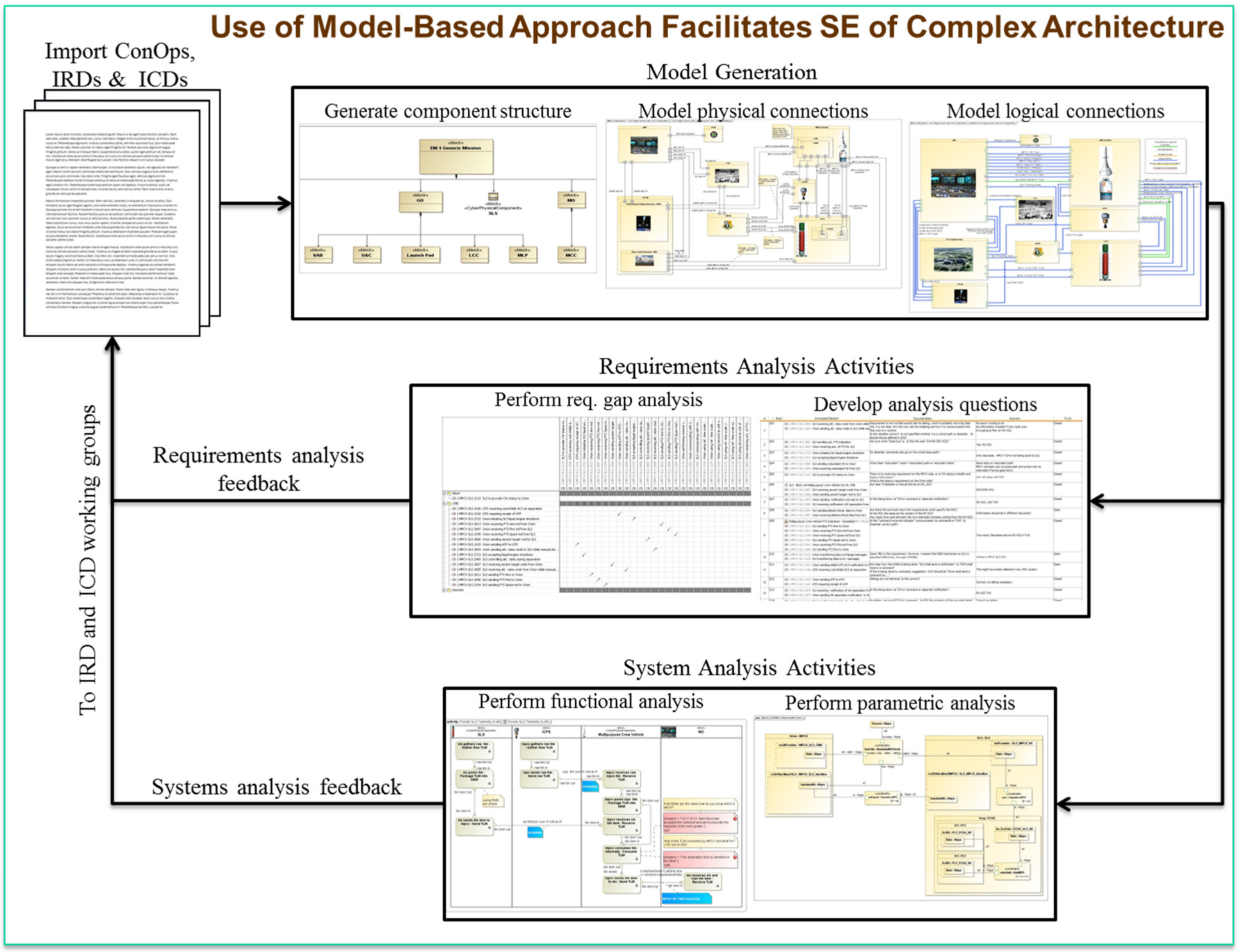

Figure 7.2-1. Model-based IRD/ICD Interface Review Process

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.

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

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.

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.

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)***

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

	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 *process* 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.

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

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

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	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01- 06 - 2014	Technical Memorandum	February 2014 - May 2014

4. TITLE AND SUBTITLE
Review of Ground Systems Development and Operations (GSDO) Tools for Verifying Command and Control Software

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Aguilar, Michael L.; Bonanne, Kevin H.; Favretto, Jeffrey A.; Jackson, Maddalena M.; Jones, Stephanie L.; Sarrel, Marc A.; Simpson, Kimberly A.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
869021.03.07.01.12

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER
L-20435 NESC-RP-14-00938

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)
NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
NASA/TM-2014-218278

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 17 Space Communications, Spacecraft Communications, Command and Tracking
Availability: NASA CASI (443) 757-5802

13. SUPPLEMENTARY NOTES

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.

15. SUBJECT TERMS
Ground Systems Development and Operations; NASA Engineering and Safety Center; Space Launch System; Multi-Purpose Crew Vehicle; Command and control software

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	32	(443) 757-5802