

Orion European Structural Test Article Propellant Tank Fill and Drain Carts

October 23 to 25, 2018

Mark Cmar

Facility and Data Systems Engineer, HX5-Sierra, LLC

Stan Grisnik

Senior Thermal Vacuum Systems Engineer, NASA

ABSTRACT



- **Environmental testing** of the Orion European Structural Test Article (E-STA), which contains the Orion European Service Module (ESM), required that the onboard propellant tanks be filled and drained with fuel and oxidizer simulant fluids as well as pressurized and depressurized with an ullage gas. This conference paper will elaborate on how these objectives were fulfilled by presenting the development of derived requirements definition, initial fill and drain concepts, selection of simulant fluids, finalization of pump and pressurization design, selection of components, selection of transfer hoses and interface connections, as well as development and maintenance of budgets, schedules, reviews, construction, documentation, and test procedures. This paper also describes implementation of checkout and commissioning activities leading to successful fluid cart pumping and pressurization operations for the test campaign.
- **The development, construction, and operation** of the fluid pumping and pressurization systems for the environmental testing of the Orion E-STA, took place at the NASA Glenn Research Center's Plum Brook Station Space Environments Complex (SEC) during 2015 and 2016.

INTRODUCTION



- **Environmental testing** of the Orion European Structural Test Article (E-STA), which contains the Orion European Service Module (ESM), required that the onboard propellant tanks be filled and drained with fuel and oxidizer simulant fluids as well as pressurized and depressurized with an ullage gas.
- **This conference presentation** will elaborate on how these objectives were fulfilled by first discussing the requirements, rationale for the chosen fill and drain method, component selection, and design calculations.
- **The discussion** will then include the design review, system construction, and checkout operations. Lastly, project budget, schedule, and scope changes will be presented.

ORION BACKGROUND [1] [2]

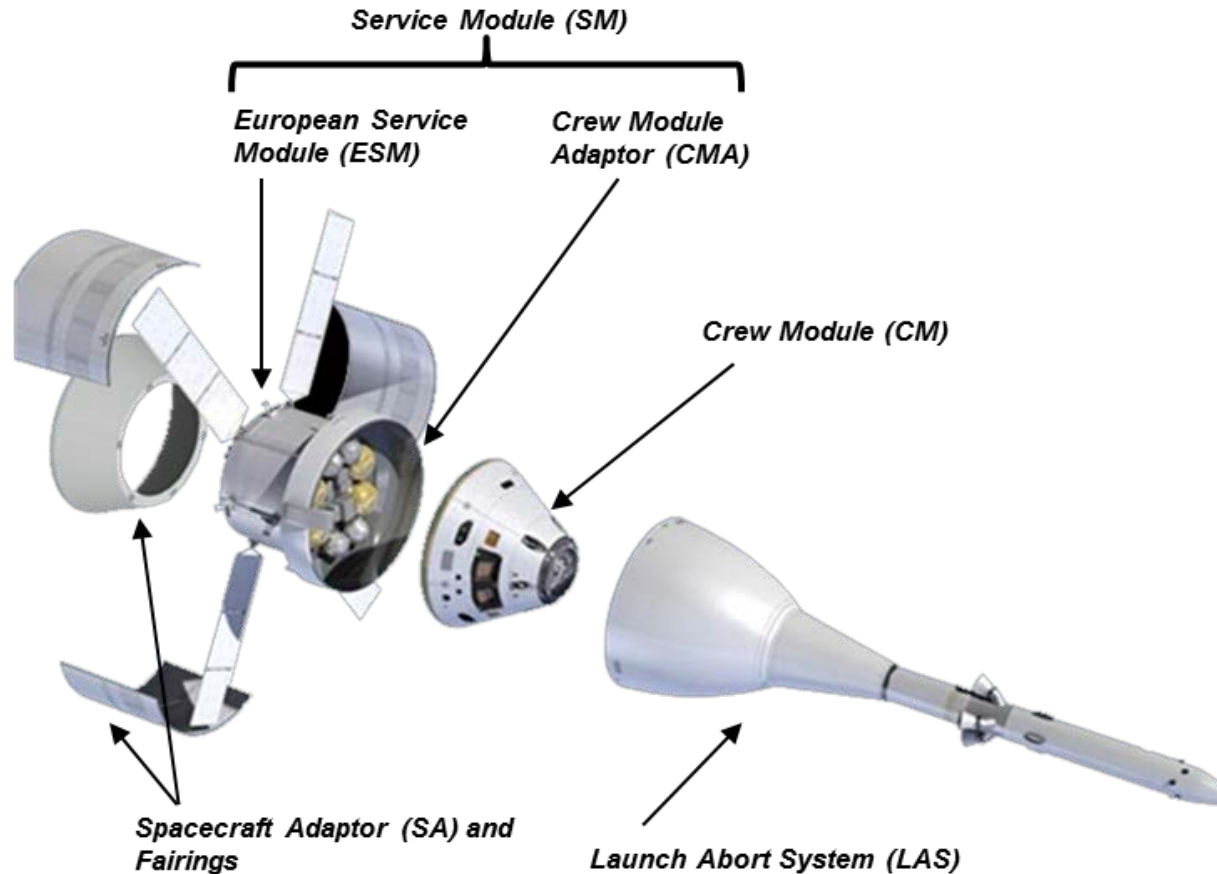


Figure 2: Orion System.

TEST ARTICLE BACKGROUND [3]



- **European Service Module (ESM) [3] [4]**

The ESM is the European Space Agency's (ESA's) contribution to NASA's Orion spacecraft that will send astronauts to the Moon and beyond. It provides electricity, water, oxygen, and nitrogen as well as keeping the spacecraft at the right temperature and on course.

TEST ARTICLE BACKGROUND [3]



Figure 3: Orion European Service Module test article.

TESTING COMPLETED [5]



Figure 6: Sensing Orion—European Service Module test article.

Space Simulation Vacuum Chamber



Figure 9: Space Environments Complex (SEC) aerial view.

Reverberant Acoustic Test Facility



Figure 10: Reverberant Acoustic Test Facility horn wall is shown at left, and the overall chamber is shown at right.

Mechanical Vibration Facility

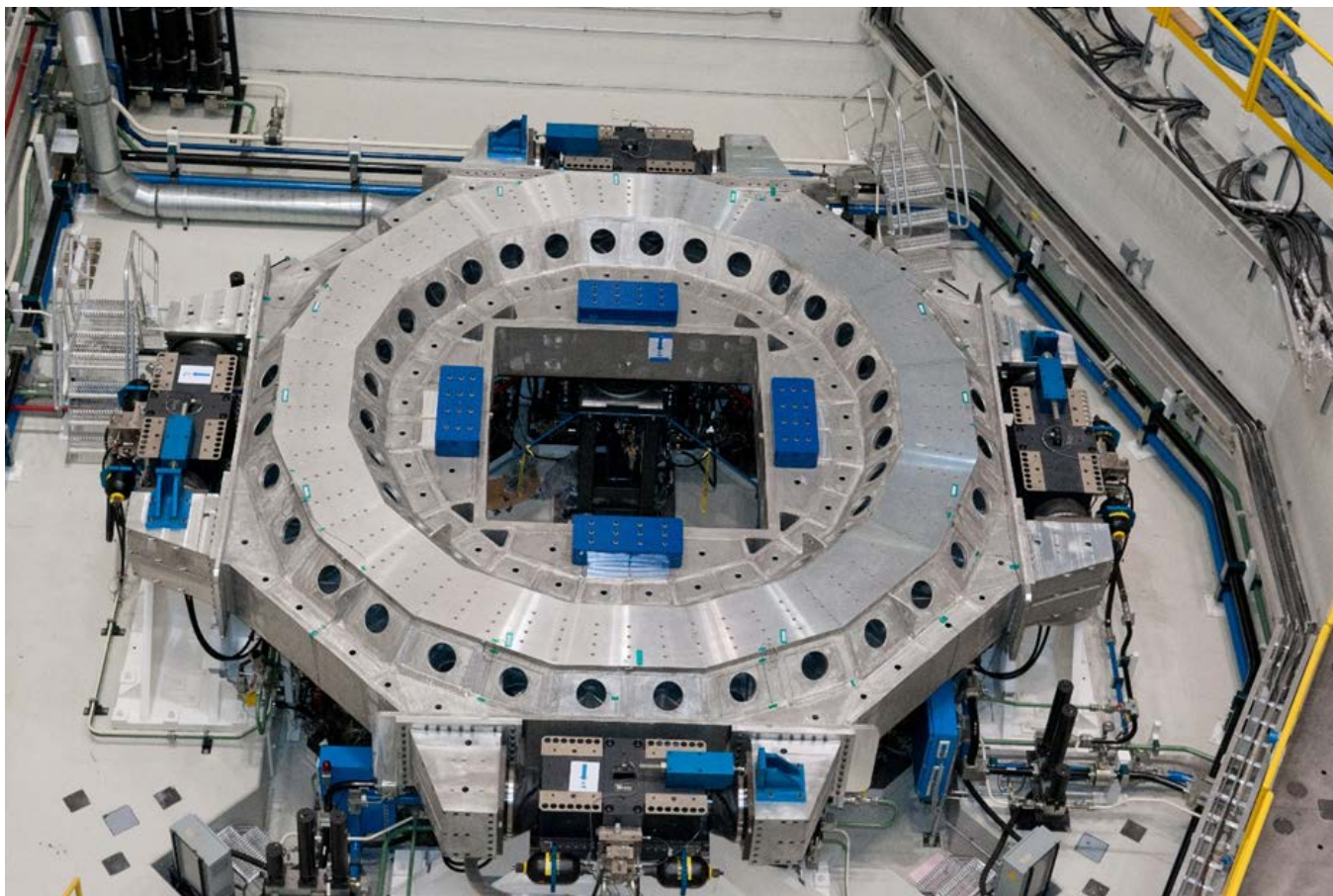


Figure 11: Overhead view of the Mechanical Vibration Facility system.

DERIVED REQUIREMENTS



- **OVERALL REQUIREMENTS**
 - **Pressurization of Oxidizer and Fuel Tanks**
 - **Fill and Drain Oxidizer Tanks**
 - **Fill and Drain Fuel Tanks**
 - 1) **Safety Requirements**
 - 2) **Contamination Requirements**
 - 3) **Operational Requirements**

INITIAL FILL AND DRAIN CONCEPTS

- Lift fluid storage tanks above the test article with crane and fill propellant tanks via gravity feed
- Place storage tanks below test article to drain
- Use pumps to fill and drain tanks
- Pressurize tanks from top of tank
- Top fill—pump type selection
- Bottom fill—pump type selection

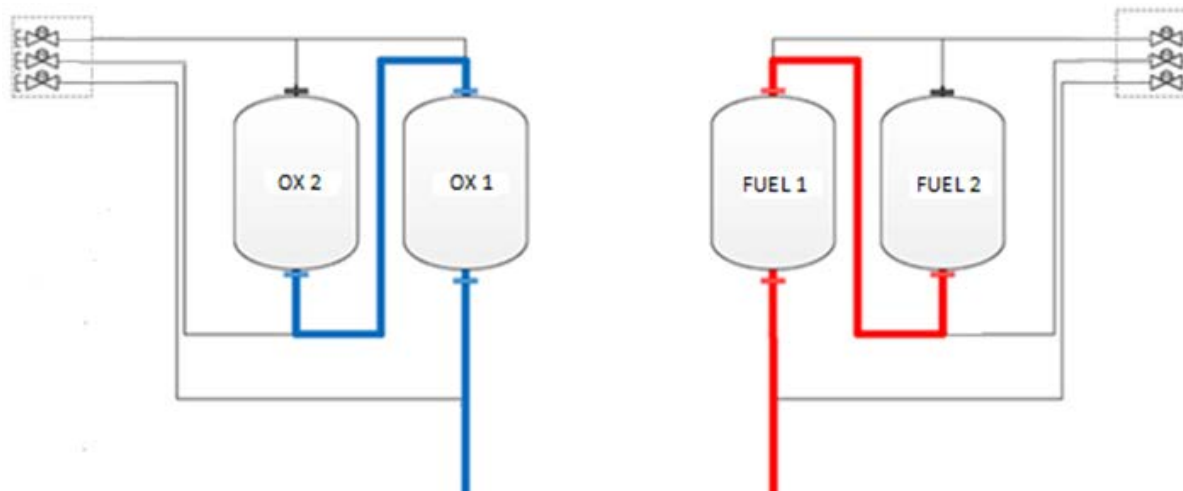


Figure 12: Basic Propellant Tank Configuration [4].

SELECTION OF SIMULANT FLUIDS



- **Oxidizer and Fuel Simulant Criteria**

- Toxicity
- Flammability
- Contamination
- Viscosity
- Specific Gravity

- **Simulants Chosen**

- Oxidizer—Novec HFE-7100 (3M™ Novec™ 7100 Engineered Fluid)
- Fuel—DI Water

- Pump Fill and Drain
- Pressurization
- Fluid Storage
- Measurement Systems
 - Fill and Drain Pressure Drop Flow Rate Calculations
 - GN₂ Pressurization Panel
 - Oxidizer Tank Pump and Cart and Components
 - Fuel Pump and Cart and Components
 - Oxidizer Simulant Storage
 - Fuel Simulant Storage
 - Weight Scales
 - Flowmeter

SELECTION OF COMPONENTS AND HOSES



- Commercial Off the Shelf (COTS)
- Material Compatible with Simulant Fluids
- Pressure Ratings
- Weight Capacity Rating
- Pumping Capacity and Flow Rates
- Pressure Drop
- Quick Disconnects

BUDGETS, SCHEDULES, AND CHANGE



- Budget
 - HFE-7100 and DI Water Estimates
 - Cost fluid simulants—DI Water and HFE-7100 and quantities
 - Skills and labor time estimates
 - Reviews, documentation, and other procurements
 - Assembly and checkout
- Schedule
- Change of Scope
 - ½-in. fill drain valves to ¼-in. fill drain valves

- **Review Process**—NASA Standards and Business Management System (BMS) Procedures
 - Design
 - Safety Review
 - Operational Readiness Review

- **Documentation**
 - Piping & Instrumentation (P&ID)
 - Panel, Cart, and Box Layout Diagrams
 - Bill of Materials
 - Operations Procedures
- **Team Effort**
 - Technician Skill Mix
 - Review design concept with technicians and seek input
 - “Hands On” Work Effort
- **Field Adaptations**
 - Assembly and Field Fit-Ups
 - Other items that were not thought of

CHECKOUT AND COMMISSIONING



- **Initial Fluid Checkouts**
 - DI Water Only
 - Priming the Pump
- **Actual Fluid Checkout**
 - DI Water/HFE-7100
- **Fluid Measurement**
 - Weight Calibrations and Verifications
- **HFE-7100 Fluid Transfer**
 - From 55 gallon drums to 350 gallon SS totes

TEST CAMPAIGN

- Multiple fills, drains, and pressurizations
- Multiple locations
- Measurement accuracy and consistency in fill and drain operations
- Nitrogen solubility in HFE-7100



Figure 17: DI and HFE Fluid Storage Totes [9] [14] on Weight Scales [16].



Figure 18: DI Water Fill and Drain Cart.



Figure 19: DI Water Portable Panel.

COMMENTS AND QUESTIONS



Thank you for your participation!

Contact Info:

Mark Cmar

Mark.D.Cmar@nasa.gov, 419-621-3273

Stan Grisnik

Stanley.P.Grisnik@nasa.gov, 419-621-3279

BIOGRAPHIES



- **Mr. Cmar** works for the contractor HX5-Sierra, LLC, at the NASA Glenn Research Center Plum Brook Station in Sandusky, Ohio. He currently is serving as a Facility and Data Systems Engineer for the Space Environments Complex (SEC). He has over 29 years of NASA experience as an instrumentation and controls engineer, data systems, project manager, deputy test program manager, and facility engineer at the NASA Plum Brook Station. He holds a BS in Electrical Engineering from the University of Pittsburgh and is a registered Professional Engineer in the State of Ohio. He is a member of the International Society of Automation (ISA).
- **Mr. Grisnik** is a civil servant at the NASA Glenn Research Center Plum Brook Station in Sandusky, Ohio. He is currently serving as the Senior Thermal Vacuum Systems Engineer for the In-Space Propulsion Facility (ISP). He has 35 years of experience as a Thermal Vacuum Systems Engineer at NASA Glenn Research Center Lewis Field and Plum Brook Station. He holds a BS in Chemical Engineering from the University of Pittsburgh and an MS in Chemical Engineering from the University of Toledo.

REFERENCES—ORGANIZATION WEBSITES



- [1] National Aeronautics and Space Administration, “Orion Spacecraft,” (September 2018). <https://www.nasa.gov/exploration/systems/orion/index.html>
- [2] MPCV 72514, “Orion Multi-Purpose Crew Vehicle (MPCV) Design Reference Missions (DRM) and Concept of Operations (CONOPS) for the European Space Agency Service Module (ESM).”
- [3] European Space Agency (ESA), “Orion European Service Module,” (November 2015). https://www.esa.int/Our_Activities/Human_Spaceflight/Orion/European_Service_Module
- [4] Airbus, “Defence and Space,” (2018). <https://orionism.airbusdefenceandspace.com/>
- [5] European Space Agency (ESA), “Testing Completed on Orion Service Module,” (December 2016). https://www.esa.int/Our_Activities/Human_Spaceflight/Orion/Testing_completed_on_Orion_service_module
- [6] NASA Glenn Research Center, “Space Environments Complex (SEC),” (July 2018). <https://www1.grc.nasa.gov/facilities/spf/>
- [7] MPCV 70156, “Cross Program Fluid Procurement and Use Control Specification.”
- [8] 3M Company, “Novec HFE–7100,” (2018). www.3m.com/Novec (3M and Novec are trademarks of 3M Company. Used with permission by trademark owners.)
- [9] Chemworld, “DI Water,” (2018). <https://www.chemworld.com/Delionized-Water-s/2622.htm>
- [10] ABZ Incorporated, “CRANE Technical Paper 410 Based Software,” (2018). <https://www.abzinc.com/index.php>
- [11] Price Pump Company, (2018). <http://www.pricepump.com/Home.aspx>
- [12] NASA Review Process Standards/Business Management System Procedures. (Design Reviews—GLP-H-7320.2; Safety Review: NASA Glenn Safety Manual—GLP-QS-8715.1; and Operational/Test Readiness Reviews—GLP-H-8720.1)
- [13] MPCV 72205, “NASA Orion Project Standards.”
- [14] Hoover Container Solutions, (2018). <http://www.HooverSolutions.com/>
- [15] Goat Throat Pumps, (2018). <https://www.goatthroat.com/>
- [16] Triner Scale & Manufacturing Company, (2018). <http://www.trinerscale.com/index.html>