# NASA Marshall Space Flight Center Human Systems Integration of the Mars Ascent Vehicle

**Tanya C. Andrews**

**NASA MSFC EV74**

**Human Factors and Integrated Logistics Engineering (HFILE) Team Lead**

**MAV HSI Lead**

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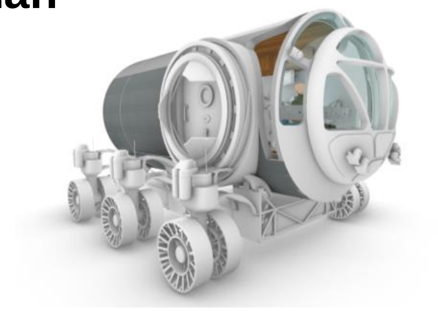
# MAV HFILE Team

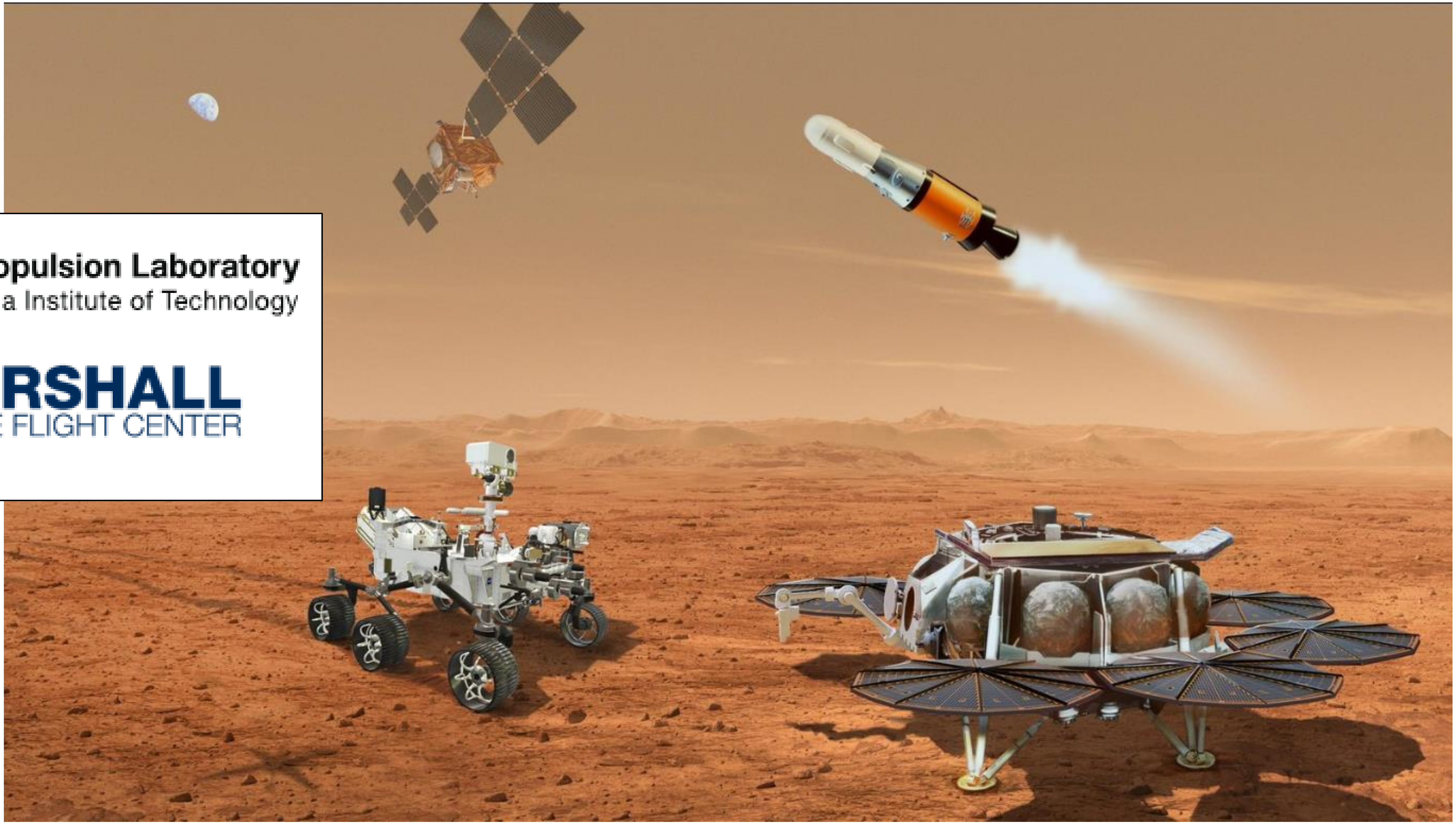
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Human Factors & Integrated Logistics Engineering

- **Paul Carothers**
  - **ESSCA Qualis**
  - **Mockup Fabrication Technician**
- **Charlie Dischinger**
  - **MSFC and NESC**
  - **HFE/HSI SME**
- **John Loomis**
  - **ESSCA Qualis**
  - **Virtual Environments Laboratory**
- **Melinda Naderi**
  - **ESCCA TriVector**
  - **SME supporting Human Factors Engineering Team**
- **Dave Perkins**
  - **ESCCA Jacobs**
  - **Integrated Logistics and Supportability**
- **Zachary Taylor**
  - **ESCCA Jacobs**
  - **Human Factors Engineering**
    - **Analysis, Mockup Design and Fabrication**



# Mars Sample Return (MSR) Concept Illustration





Jet Propulsion Laboratory
California Institute of Technology

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# Mars Sample Return (MSR) Mission Overview

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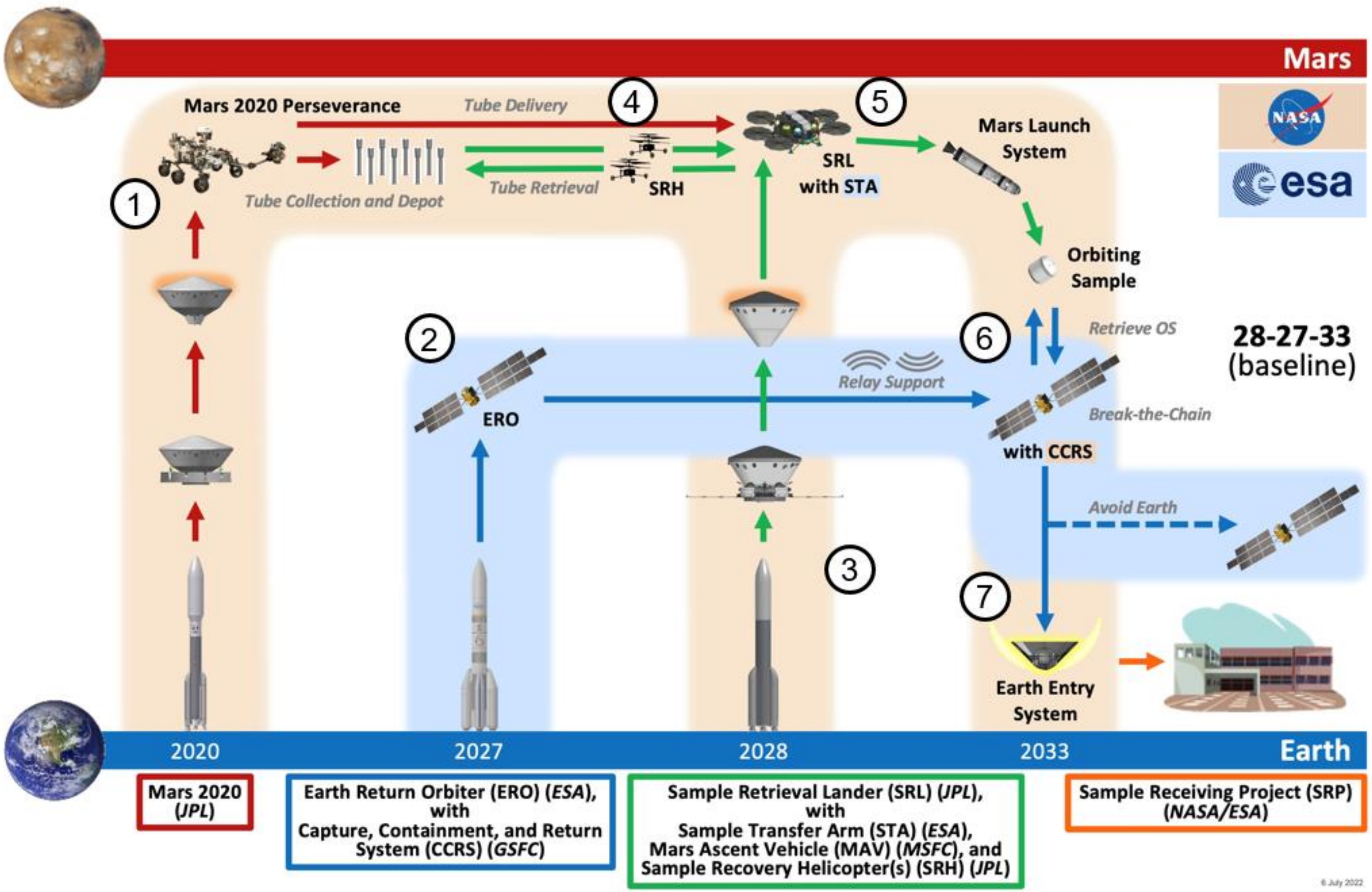
MSR Mission Objective:

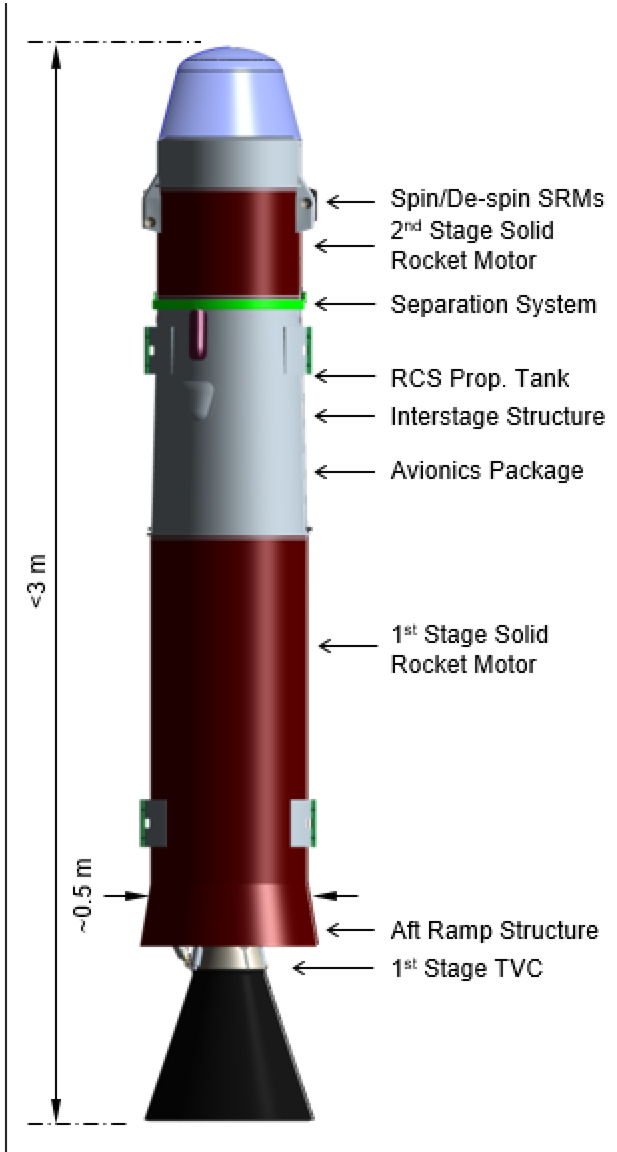
Retrieve Mars samples and return to Earth.

1. Mars 2020 rover collects Mars samples and retains some tubes and leaves some tubes in place.
2. Earth Retrieval Orbiter (ERO) sent to Mars orbit.
3. Mars Lander Platform (MLP) with Mars Ascent Vehicle (MAV) sent to Mars.
4. Mars 2020 delivers sample tubes to MLP, or Sample Recovery Helicopters (SRH) recover sample tubes left on Mars surface.
5. Orbiting Sample (OS) on the MAV receives the sample tubes. MAV carries the OS to Mars orbit.
6. ERO rendezvous with OS, retrieves OS, and returns OS to Earth.
7. Earth Entry Vehicle returns OS to Earth's surface.



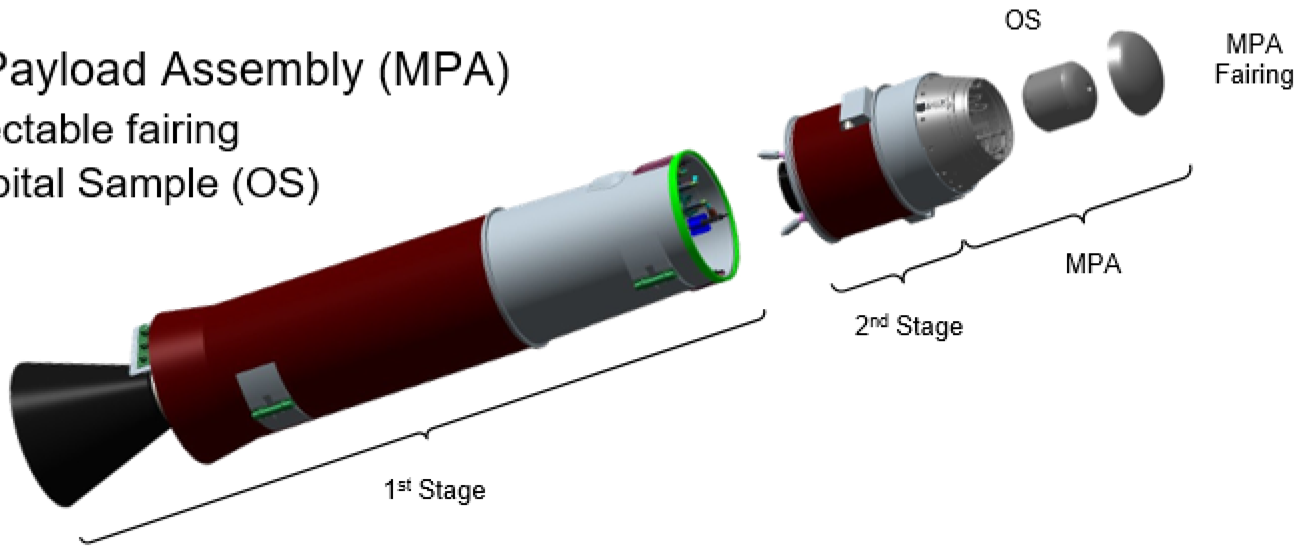
# Mars Launch System (MLS=MAS) {Design has been updated.}





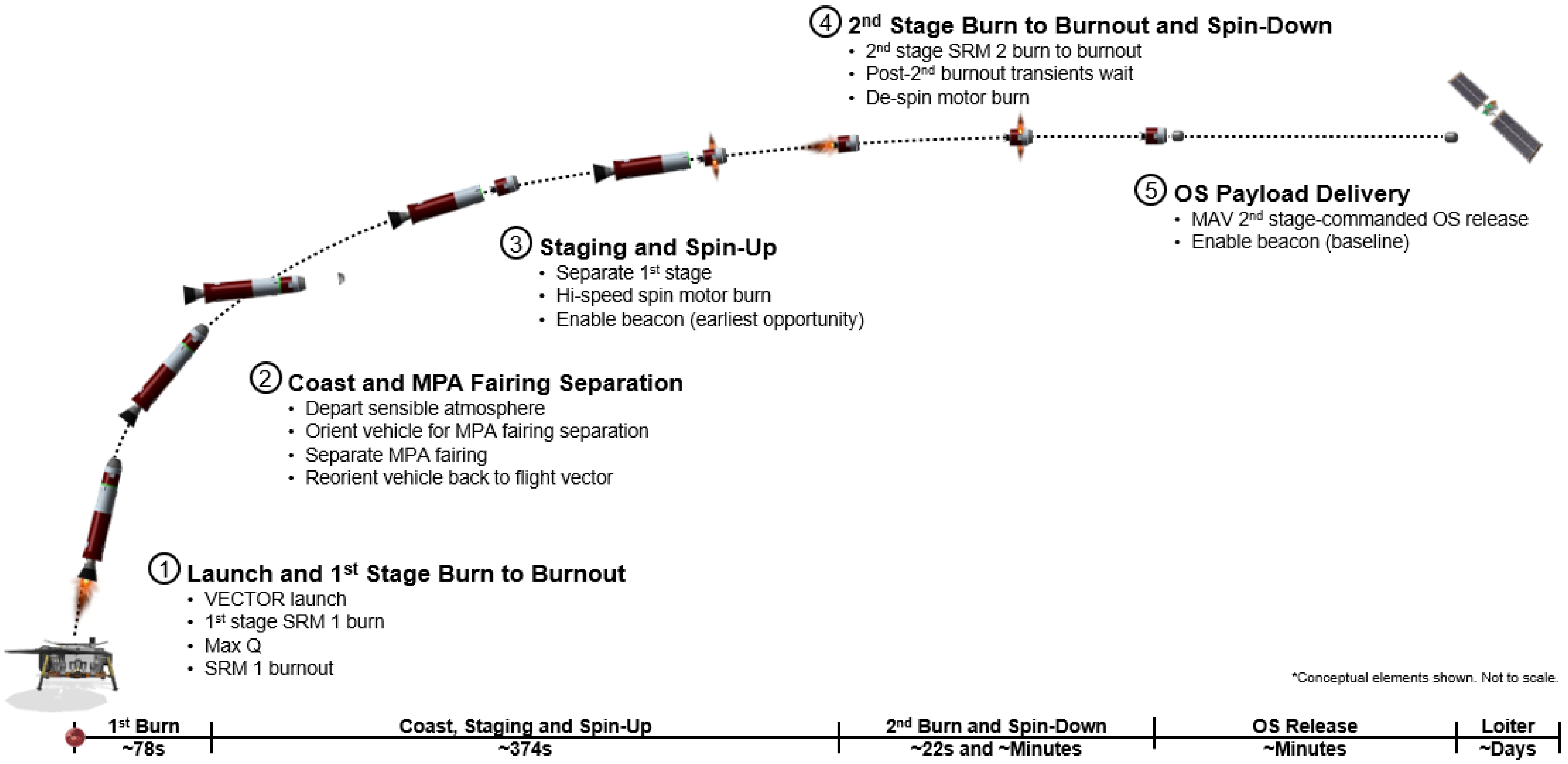

SRC Mars Ascent System (MAS) consists of:

- Mars Ascent Vehicle (MAV)
  - Two-stage (guided, unguided) solid motor vehicle
  - Pyrotechnic stage separation
  - Electrical-mechanical Thrust Vector Control (TVC) with supersonic splitline nozzle on 1st stage
  - 2x Spin Motors and 2x De-spin motors on 2nd stage
  - Monopropellant Reaction Control System (RCS)
- MAV Payload Assembly (MPA)
  - Ejectable fairing
  - Orbital Sample (OS)



# MAV Ascent Mission Operations Overview

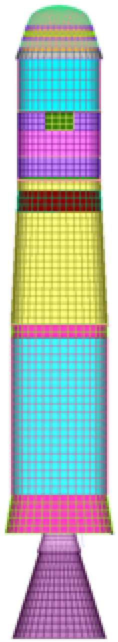




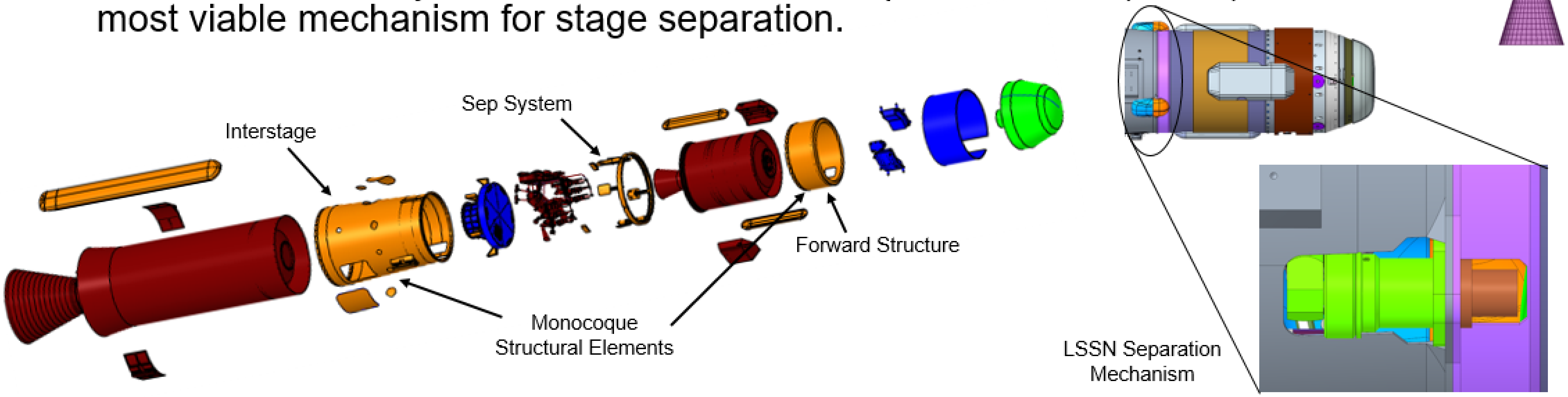
# Structural and Mechanical Design {Design has been updated.}



- Unique structural design challenge as vehicle must survive approximately 15g lateral loads during Mars EDL.
- Primary load path travels through SRM1 and interstage via VECTOR attach points.
- Structural design based upon quasi-static loads analysis during Earth ascent/EDL and dynamic loads during VECTOR ejection and Mars ascent. FEM developed.
- Non-propulsive structural elements designed of high TRL machined monocoque construction from simple ring forgings.
- Detailed trade study determined Low-Shock Separation Nuts (LSSN) as most viable mechanism for stage separation.

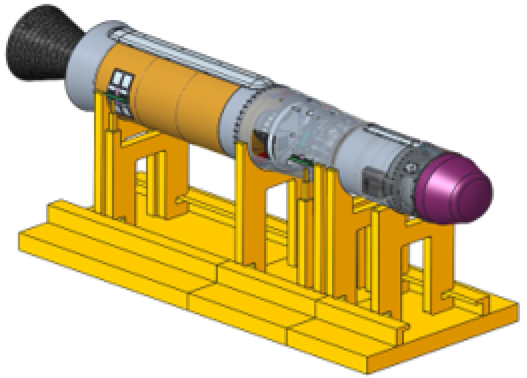


Mars Ascent FEM

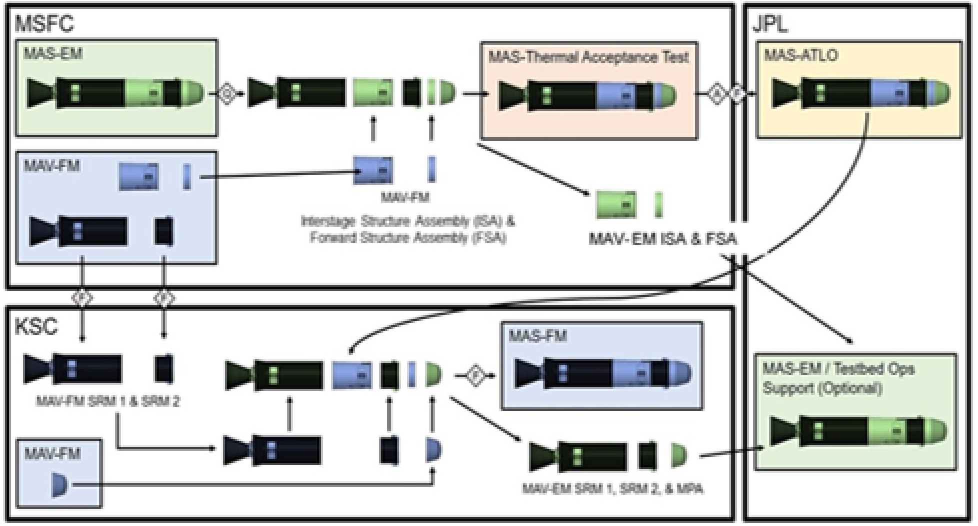


# MAV Assembly Integration and Test

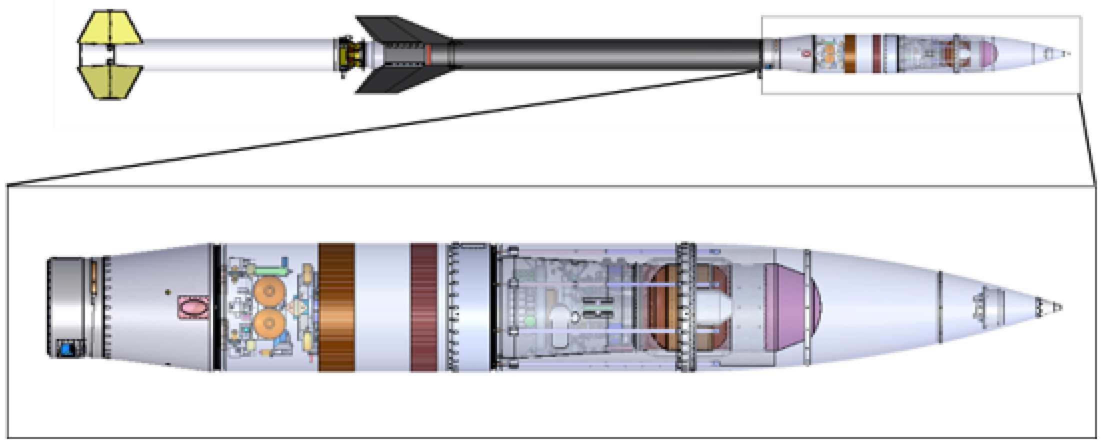
- AI&T planning included vehicle assembly from subsystem components, integration with external elements, Verification & Validation (V&V) activities, and the development of a concept for an Earth-based flight test program.
- Four MAV units planned as part of SRC: Engineering Model (EM), Flight Test (FT) unit, Assembly/Test/Launch Operations (ATLO) unit and Flight Mission (FM) unit.
- Rigorous ground-based qualification and acceptance testing planned for individual subsystem assemblies, including hardware-in-the-loop and flight software integration, where applicable. Eleven major test activities for V&V.
- Integrated S2 Earth-based flight test planned, delivered to high altitude via sounding rocket to replicate Martian surface environments.



Notional Qualification Test Article




Assembly & Integration of EM, FM, and ATLO



Flight Test Unit as Payload in Sounding Rocket

# MAV Human Systems Integration (HSI)

Human Factors & Integrated Logistics Engineering

- **Human Factors Engineering and Integrated Logistics and Supportability provide support to MAV through the AI&T team**
- **MAV Flight Test SRR**
  - Comment was submitted about the lack of an HSI plan
- **NPR 7120.5F released Aug 3, 2021, requiring HSI Plans for all Projects, Single-Project Programs, and Tightly-Coupled Programs**
- **NPR 7123.1D soon followed with a requirement for HSI Plans**
- **HSI vs. Human Factors Engineering (HFE)**
  - Human factors engineering is to human systems integration as mechanical engineering is to systems engineering. HSI brings together and coordinates six related domains; HFE is included in one of those six domains.
- **HSI is a "total systems" approach: all humans/human behavior* in the system must be considered**
- **HSI is integrated through the Systems Engineering MAV Team.**

# HSI Wheelhouse



**EV74**
**Functions**


**Humans/Human Behaviors: users/operators; ground controllers; monitoring personnel; trainers; integration and test personnel; manufacturers; maintainers; assembly personnel; logistics personnel; automation/autonomous systems that mimic human decision making and action (where humans provide the requirements).*

NASA HSI Handbook

# MAV HSI Approach



- MAV Systems Engineering responded to HSI comment with an integrated HSI plan located in the MAV Project Plan (MAV-001).
- HSI support was already primarily funded through AI&T, so function remained in SE, but supported through AI&T

3.6.2.1.9 Human Systems Integration (HSI) Lead

The MAV HSI Lead is responsible for providing integrated HSI input, in conjunction with project management and systems engineering, and is responsible for insight and oversight of the MAVIS contractor's implementation of HSI processes throughout the MAV life cycle. The MAV HSI Lead will work with representatives from each HSI domain to identify, resolve, and track HSI issues and report on analyses of these issues to the MAV Project SE&I.

The MAV HSI Lead provides insight and oversight of the MAVIS contractor's performance of HSI assessments, studies, analyses, and execution of system-level HSI activities. The MAV HSI team and HSI Lead develop the MAV HSI Plan portion of the Project Plan and updates the HSI Plan as required by NASA and MAV Project documentation.

The HSI Lead engages in all project phases, including participation in Program and Project milestone reviews over the MAVIS contractor's HSI activities and products for the entire life cycle of the MAV. The HSI Team performs insight and oversight of MAVIS contractor-developed HSI products pursuant to the goal of life-cycle cost containment.

# MAV HSI Plan



## 3.32 MAV HSI Plan

The MAV Human Systems Integration (HSI) Plan is imposed by NPR 7120.5 and MPR 7120.1. It addresses implementation of HSI activities and products through the NASA systems engineering and project life-cycle processes to ensure the full integration of the human element with all other components of the system. The MAV HSI effort described ensures the application and integration of MAV-appropriate NASA HSI domains. This includes all aspects of the MAV life cycle. The key to a successful HSI strategy is integration of the HSI Lead with the SE&I technical management processes in the Program and is dependent on the comprehensive integration and collaboration of HSI products and processes across all HSI domains. The HSI Lead is responsible for alignment with the MAV Project Plan and other control documents and for maintenance of a schedule of key HSI milestones.

The HSI strategy is managed by the MAV HSI Lead to ensure that the HSI requirements for all appropriate domains are accurately defined, verified with appropriate methodology and success criteria, and the products validated through developmental test and evaluation activities.

The HSI Lead is responsible for providing integrated HSI input, in conjunction with project management and systems engineering, and is responsible for implementing HSI processes throughout the MAV life cycle. The HSI lead will work with representatives from each HSI domain to identify, resolve, and track HSI issues and report on analyses of these issues to the MAV Project SE&I.

# MAV HSI Domains



## 3.32.1 HSI Domains

This section identifies the HSI domains applicable to MAV including rationale for their relevance.

Additionally, this section describes the HSI issues that involve potential technical, cost or schedule risks

(1) Human Factors Engineering (HFE)
For the MAV, the HFE effort ensures the MAV system design provides an effective and efficient interface for the Ground Processing functions of vehicle assembly and Corrective Maintenance. The HFE lead assures creation, management and implementation of HFE requirements across all systems and equipment, to assure the MAV will be designed and developed with focus on the integration and accommodation of the human performance characteristics of the Ground Crews. The Human Factors Engineering requirements can be found in Section 3.6 of MAV-058 Design and Construction Standards (D&C) Plan.

(2) Operations
Operations for MAV includes designing systems to enable safe, robust, cost-effective operations for human effectiveness and mission success. It involves consideration of lessons learned from past operations in other programs in conjunction with mission objectives for the current program, in the development of concepts of operations (ConOps), procedures, and function allocation. Operational trade studies completed by the MAV Project for key decisions that would impact program costs are part of the HSI Team roles and responsibilities. The MAV-004 Concept of Operations (ConOps) Document supports the implementation of the operations domain for the MAV project.

(3) Maintainability and Supportability (M&S)
Maintainability and Supportability addresses design, development, and execution of simplified maintenance and optimization of resources, spares, consumables, and logistics, given corresponding mission constraints and objectives. The primary goal of the MAV Supportability Engineering efforts is to ensure that the MAV is fully operable, maintainable, and available in its intended environment at minimum life cycle cost. Current supportability analyses include assessing the MAV Element's Maintenance Task Analysis, analysis of current risks to supportability, and the support system trade assessments. The MAV Integrated Logistic Support Plan, described in section 3.13 of this document, supports the MAV implementation of this domain.

(4) Safety
Safety and Mission Assurance (SMA) for the MAV program leads efforts related to safety analyses, reliability, quality assurance, and hazard analyses. The MAV HSI lead works with MAV SMA to assure appropriate reliability and maintainability processes and requirements are in place to support M&S and other domains. Section 3.2 of this document discusses the Safety and Mission Assurance Plan in more detail.

(5) Training
Training within the MAV program has not yet been identified. Training needs will be examined as they arise. HSI will advise SE and project management on schedule associated with training strategies and decisions.

# HSI Implementation



## 3.32.2 HSI Implementation

HSI is a continuous, iteratively applied process. The MAV HSI Lead performs HSI assessments, studies, and analyses and executes system-level HSI activities. The HSI team and Lead develop the HSI Plan portion of the Program Plan and updates as required by NASA and Program documentation.

The HSI Lead engages in all project phases, including participation in Program and Project milestone reviews to conduct HSI activities, develop HSI products, collaborate with subject matter expertise for specific tasks across the project disciplines, and support the entire life cycle of the MAV. The HSI Team develops HSI products as identified by the HSI Lead, the MAV Project SE&I, or the Program Manager pursuant to the goal of life-cycle cost containment.

# What is ILS?



- Integrated Logistics Support (ILS) otherwise known as Integrated Product Support (IPS) is an integral part of the Systems Engineering process.
- ILS is not point A to point B shipping but rather operations support planning.
- ILS has three main goals:
  - Reduce Life Cycle Cost (otherwise known as Total Ownership Cost)
  - Reduce the Operations Support Footprint
  - Ensure designs are supportable and maintainable
- For MAV the goal is support of the assembly process
  - Proper planning reduces the likelihood of schedule delays and cost overruns

# MAV ILS Discussion



- The ILSP provides guidance on “what” needs to occur.
  - Guidance, not hard requirements
  - Project level plan
- Two DRDs on PDP and LPD
  - PDP: Product Development Plan (i.e. the MAVIS ILSP)… “how” guidance will be enacted
  - LPD: Logistics Product Data (LSAR in .xls or similar to track configuration and generate reports – database not required)
  - The DRDs allow oversight of MAVIS activities and product configuration

# ILS Products



- Logistics Support Analysis Report (LSAR)
  - Interactive database (or simple spreadsheet for less complex projects like MAV)
  - Produces Reports/LPD such as:
    - Level of Repair Analysis (LORA)
    - Maintenance Task Analysis (MTA)
    - Maintenance Significant Items List (MSI)
    - Spare Parts List
    - Critical Items List (CIL)
    - Reliability Centered Maintenance (RCM)
    - Tools List
- ILS Plan (ILSP)/Product Development Plan (PDP)
  - Required per NPD 7500.1 (and NPR 7120.5)
  - The ILSP/PDP covers how the product will be supported in all phases and is tailored to meet the specific needs of the program.
    - For MAV the focus is on support during the assembly process.
      - Proper planning reduces the likelihood of schedule delays and cost overruns.

# The Ten ILS Elements



- Maintenance Support
- Supply Support
- Special Tools and Test Equipment
- Facilities
- Computer Resources
- Personnel
- Packaging Handling Storage and Transportation (PHS&T)
- Reliability and Maintainability/Equipment Design
- Technical Data/Publications
- Training

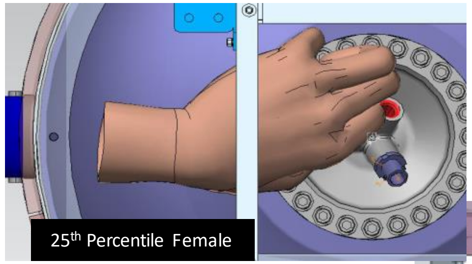
# MAV Human Factors Engineering

- The MAV Human Factors Engineering (HFE) Team supports the development of MAV design, assembly, and ground processing operations
- The team is responsible for determining and levying appropriate HFE requirements on the MAV design
- The HFE team is responsible for verifying that MAV designs and ground operations meet the established requirements set
  - Worksite analyses for the design and use of MAV Ground Support Equipment (GSE)
  - Worksite analyses for MAV assembly and integration activities
  - Virtual Reality (VR) assessments of hardware designs to identify areas for potential improvement
  - Verification of HFE Requirements

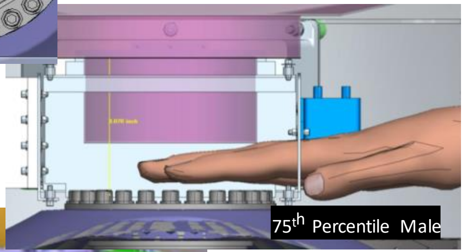
# HFE Analysis Methods

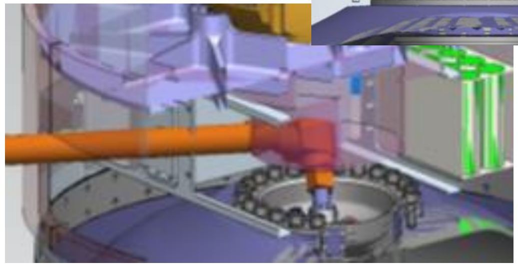


**Physical Analyses** use mockups to allow physical assessment of a design

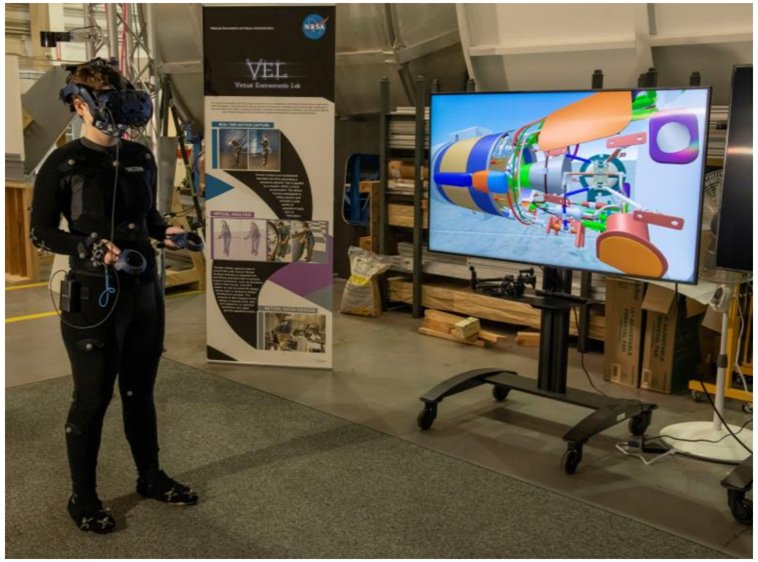



**Virtual Analyses** using Process Simulate Human (PSH) to assess access, work envelope, reach, line of sight etc., for the required female and male percentiles, as well as, assessing tool fit and function.

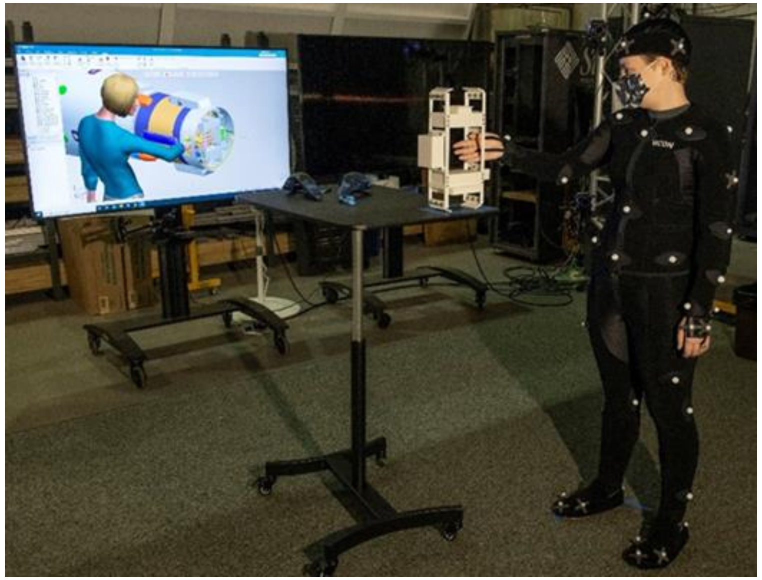


**Mixed Reality Analyses** merge real and virtual objects utilizing 3-D printed mockups within the VEL provides passive haptics and real dynamics to test subject performing assessment

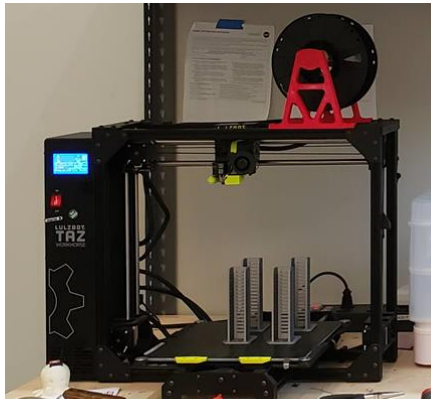



**Virtual Reality Analyses** allow users to interact with the model in a completely virtual world. This can be combined with Motion Capture to improve the assessment



# Human Factors Engineering (HFE) Capabilities in EV74






## Cost effective for projects

- Capabilities have been built through large project funding

## Human Factors Analysis of designs and processes

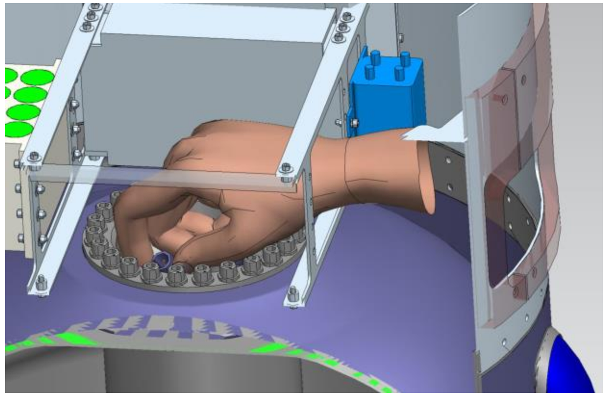
- Virtual Assessments using VR Environment and Motion Capture (MoCap)
- Process Simulate Human (PSH) human modeling and simulation tool
- Assessments using physical mockup or part-task mockup
- Table top evaluation of design drawings

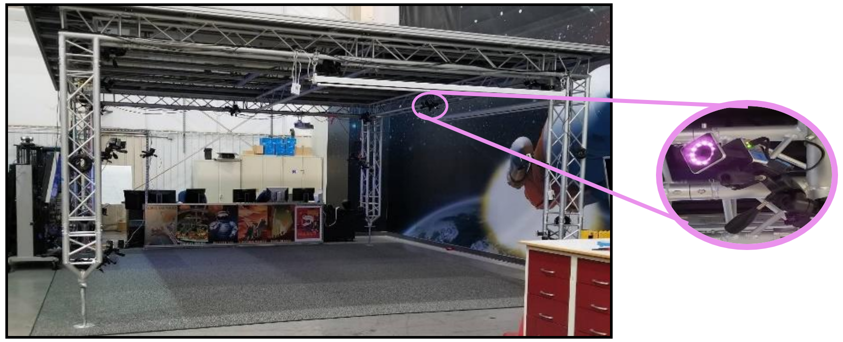
## Mockup Fabrication

- Metal, Plastics, Composites and Wood

## Rapid Prototyping through 3-D print production

- Fused Filament Fabrication

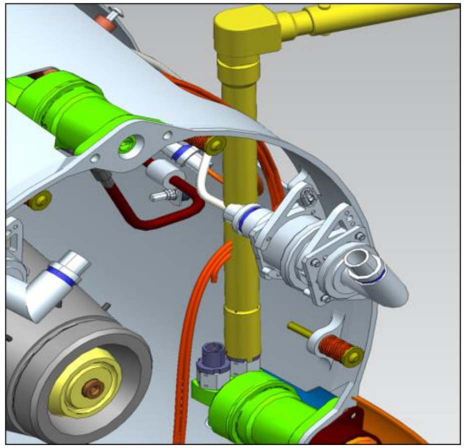




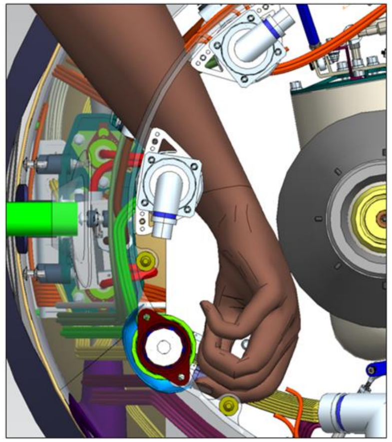
# HFE Virtual Analysis using Process Simulate Human (PSH)

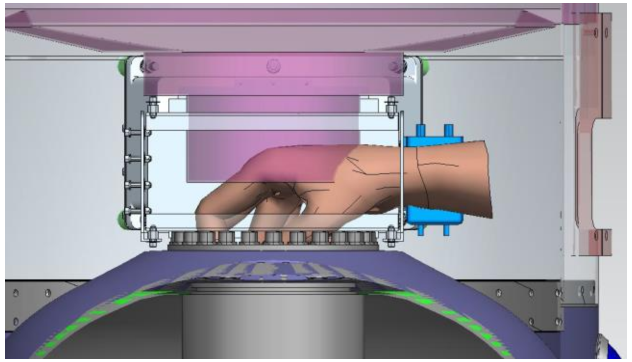


Process Simulate Human (PSH) human modeling and simulation tool provides the ability to quickly assess designs for *access, work envelope, reach, line of sight etc*, for required anthropometric variances, as well as assessing tool fit and function.



**MAV Tool Clearance Assessment**



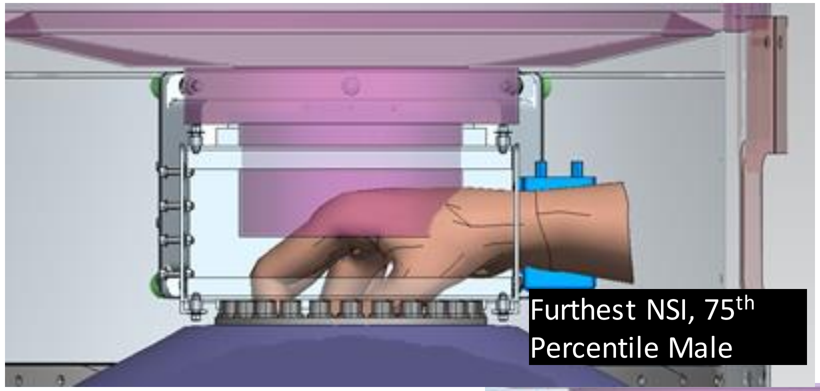


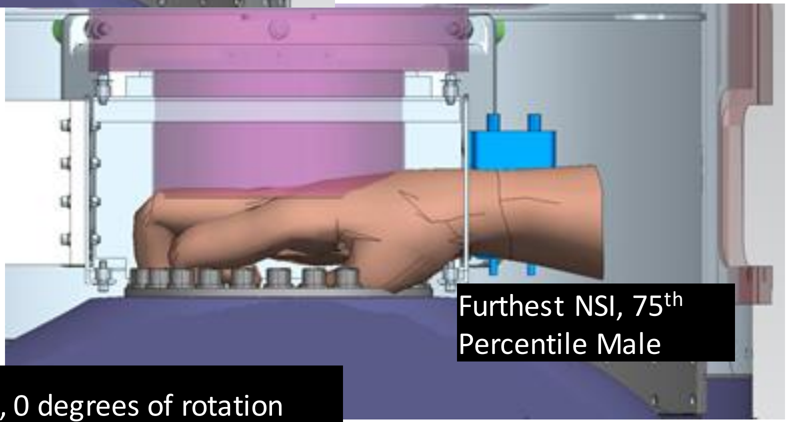
**NSI Access Studies**

# SRM2 Forward NSI R&R Assessment

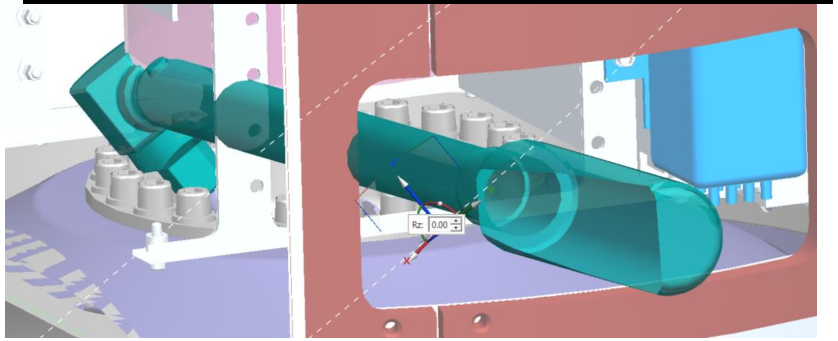


- Problem
  - PDC Rev0 designs placed the NSIs for SRM2 in the forward end of the motor.
  - Inert NSIs need to be switched for active NSIs during the assembly process.
- Action
  - Assessed operation to remove and replace NSIs, considering work envelope volume and reach access for tools and a range of operators
- Conclusion
  - All hands assessed violated keep out zones
  - Access was very limited and awkward for users
  - Inadequate clearance for tools
  - This assessment supported the decision to move the SRM2 NSIs to the current configuration.


Furthest NSI, 75th Percentile Male


Furthest NSI, 75th Percentile Male

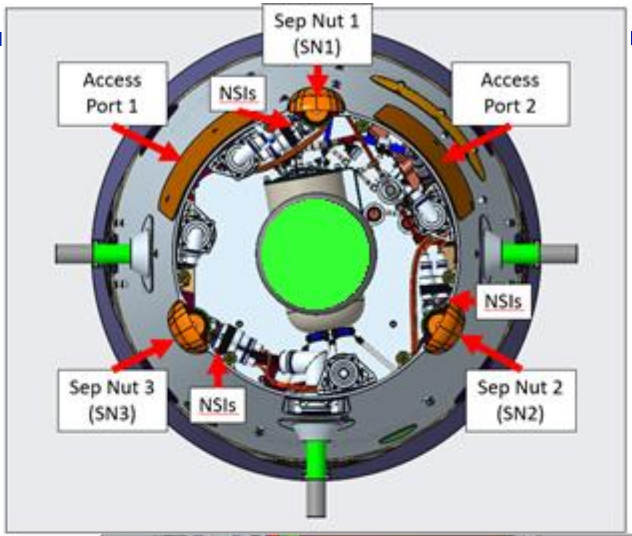
Furthest NSI, -10 degree head angle, 0 degrees of rotation

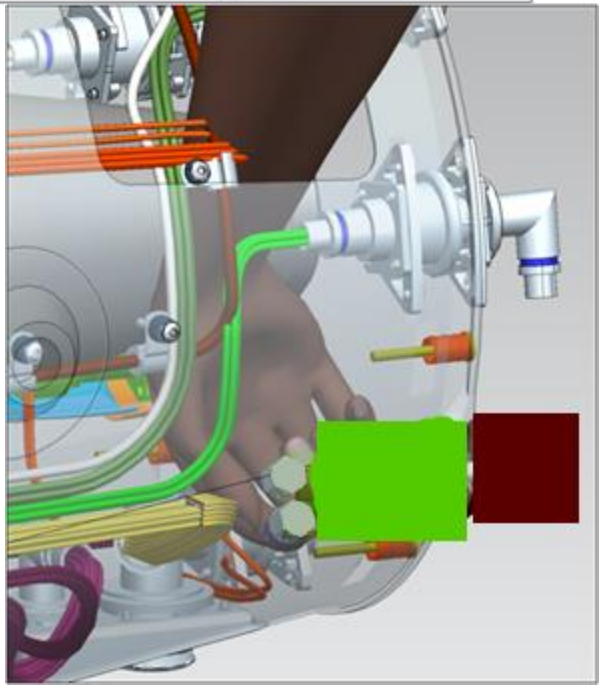


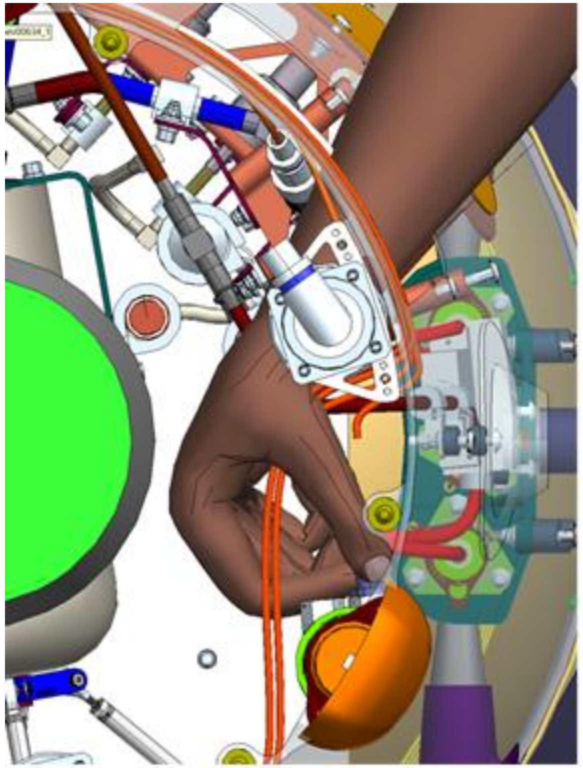
# Separation Nut NSI Assessment



- Problem
  - PDC Rev1 places 3 pairs of NSIs 120°apart with one NSI close to the wall and the other toward the center of the vehicle
  - Inert NSIs need to be switched for active NSIs during the assembly process
- Action
  - Assessed operation to remove and replace NSIs, considering work envelope volume and reach access for tools and a range of operators



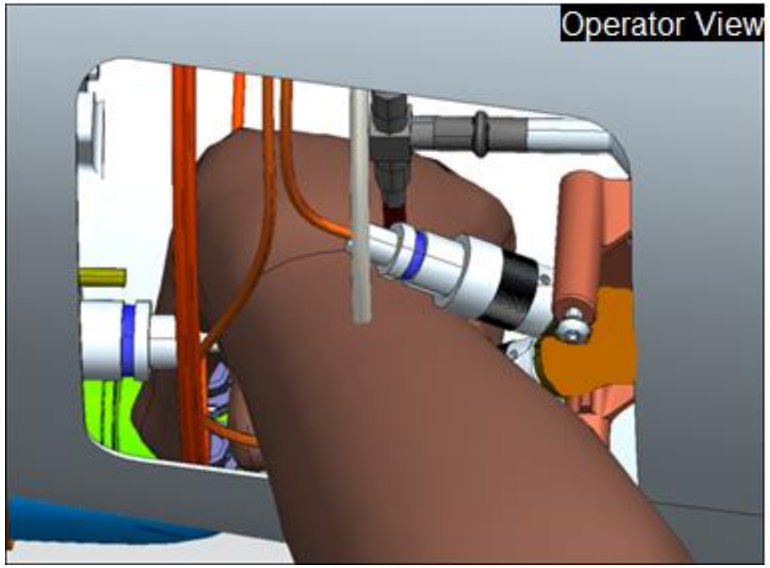



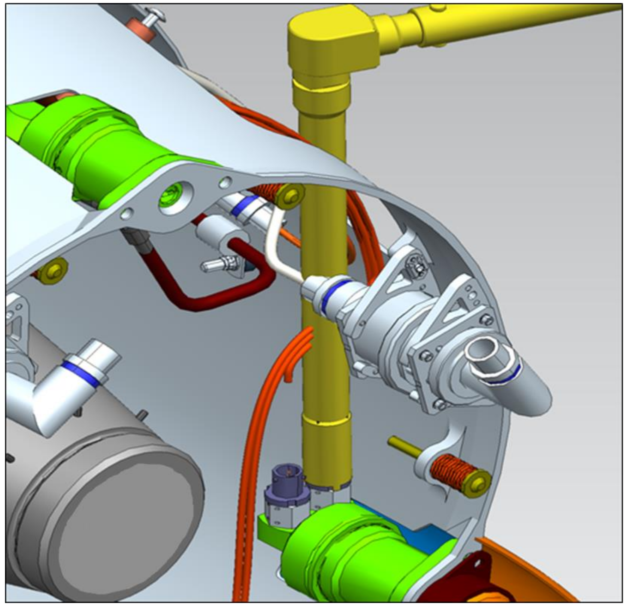


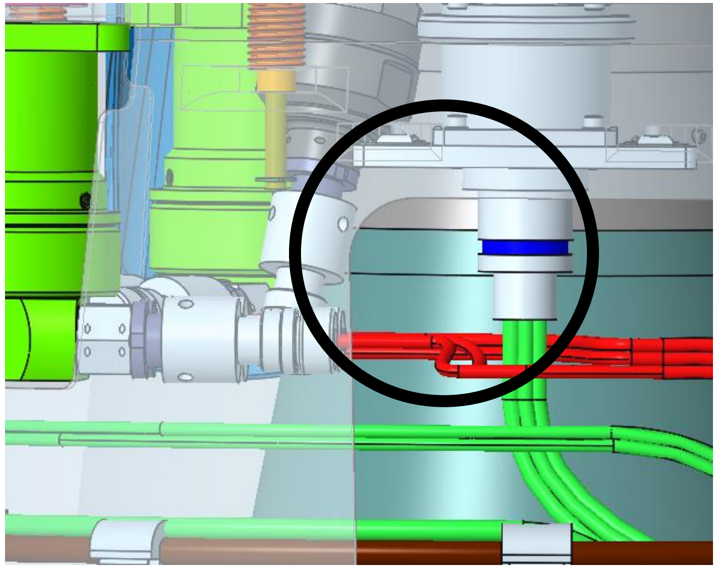
# Separation Nut NSI Assessment (cont.)



- Conclusion/Design Feedback
  - Orientation of SN3 precludes wrench access
  - Visual Access is limited
  - Cabling and tubing should be routed around access volume
  - Zero force connectors may impede ability to place connectors on NSIs
- Forward Work
  - Re-assess with updated, smaller access ports
  - Consider new tasks



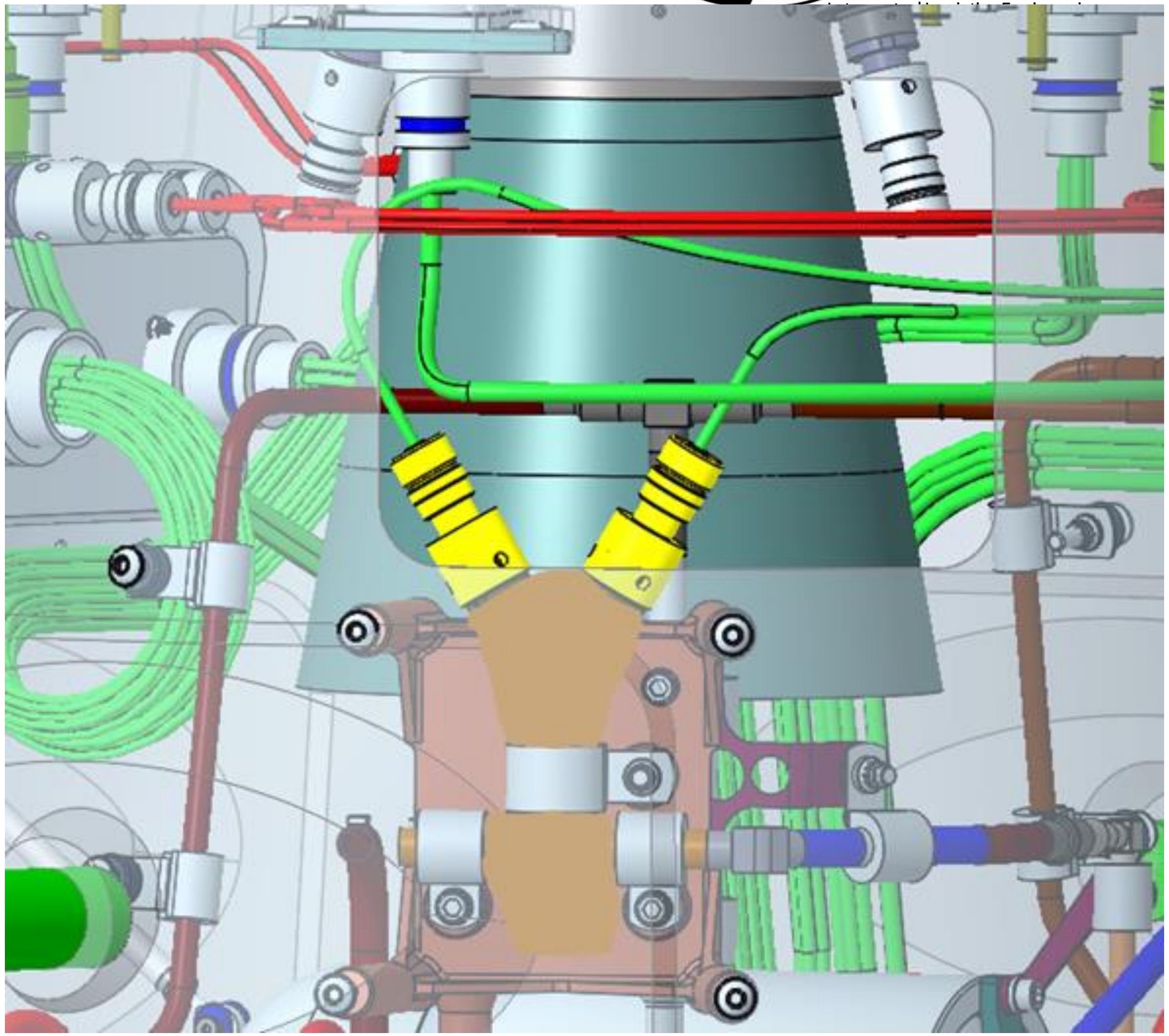





# RCS Pyrovalve NSI Assessment



- Problem
  - Stages are assembled with Faraday caps on the Pyrovalve NSIs
  - Faraday cap must be removed
  - Wires must be checked for no voltage
  - Flight connections must be made
- Action
  - Evaluate access to Pyrovalve NSI for this operation, including a two-handed operation for no-volt check
- Conclusion
  - Forward Work



# HFE Analysis using Virtual Environments Laboratory (VEL)



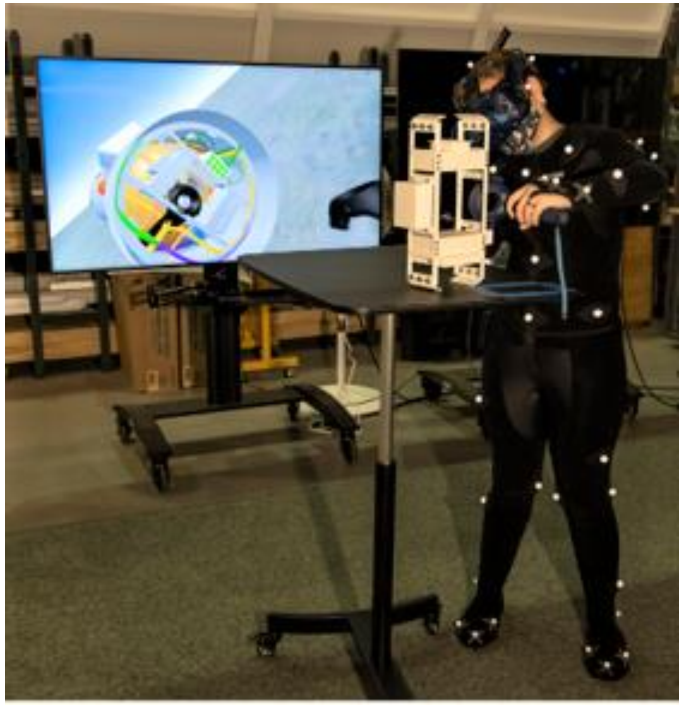
VR environment operating Process Simulate Human (PSH) software and using Vicon Motion Capture (MoCap) Camera System along with MoCap suits, Headsets and associated hardware

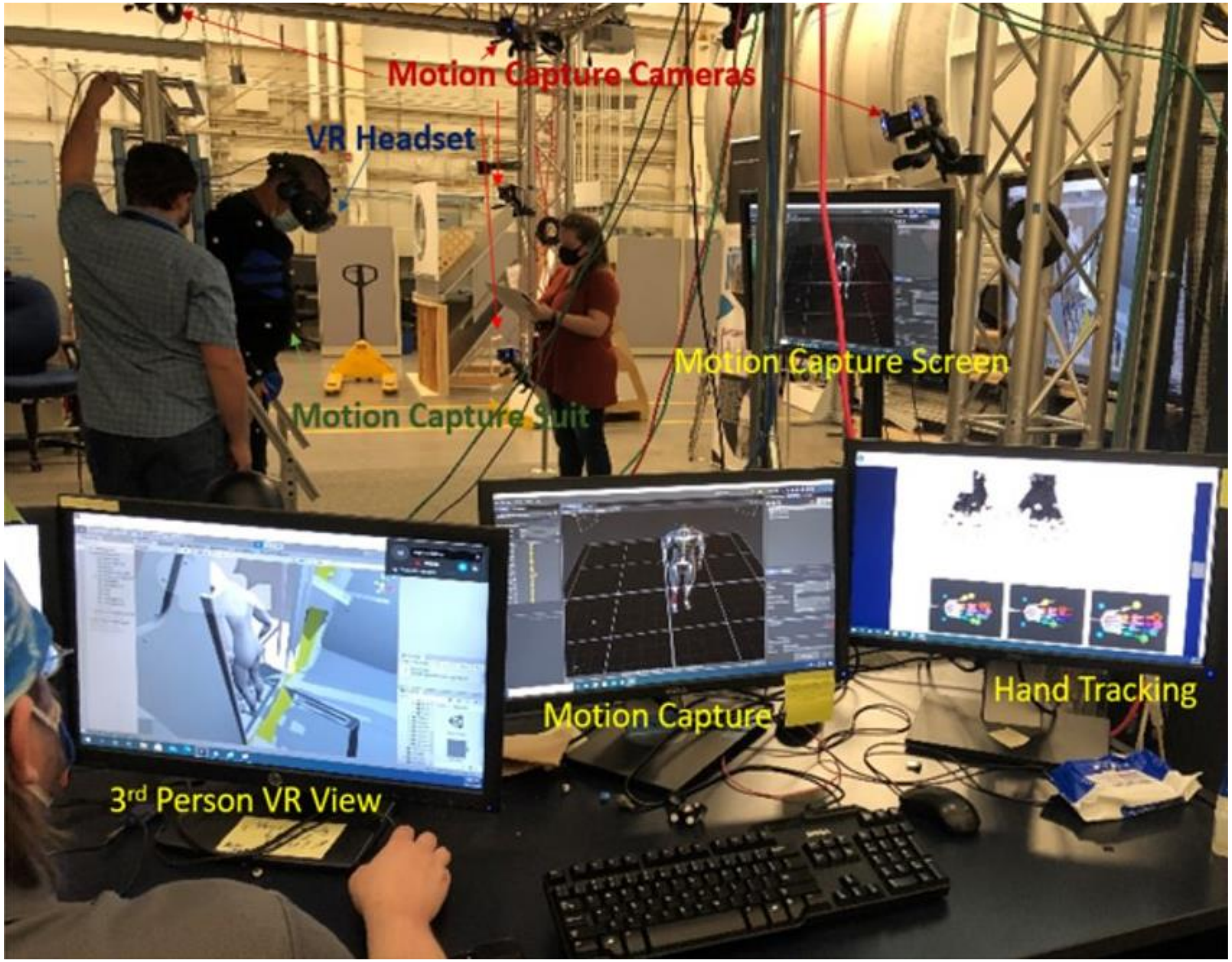

Immersive Virtual Reality Environment

# HFE Analysis using Integrated Physical and Virtual Environments Laboratory (VEL) Tools



**Merging Physical and Virtual:**
Utilizing 3D printed mockup within VR to provide passive haptics and real dynamics to test subject





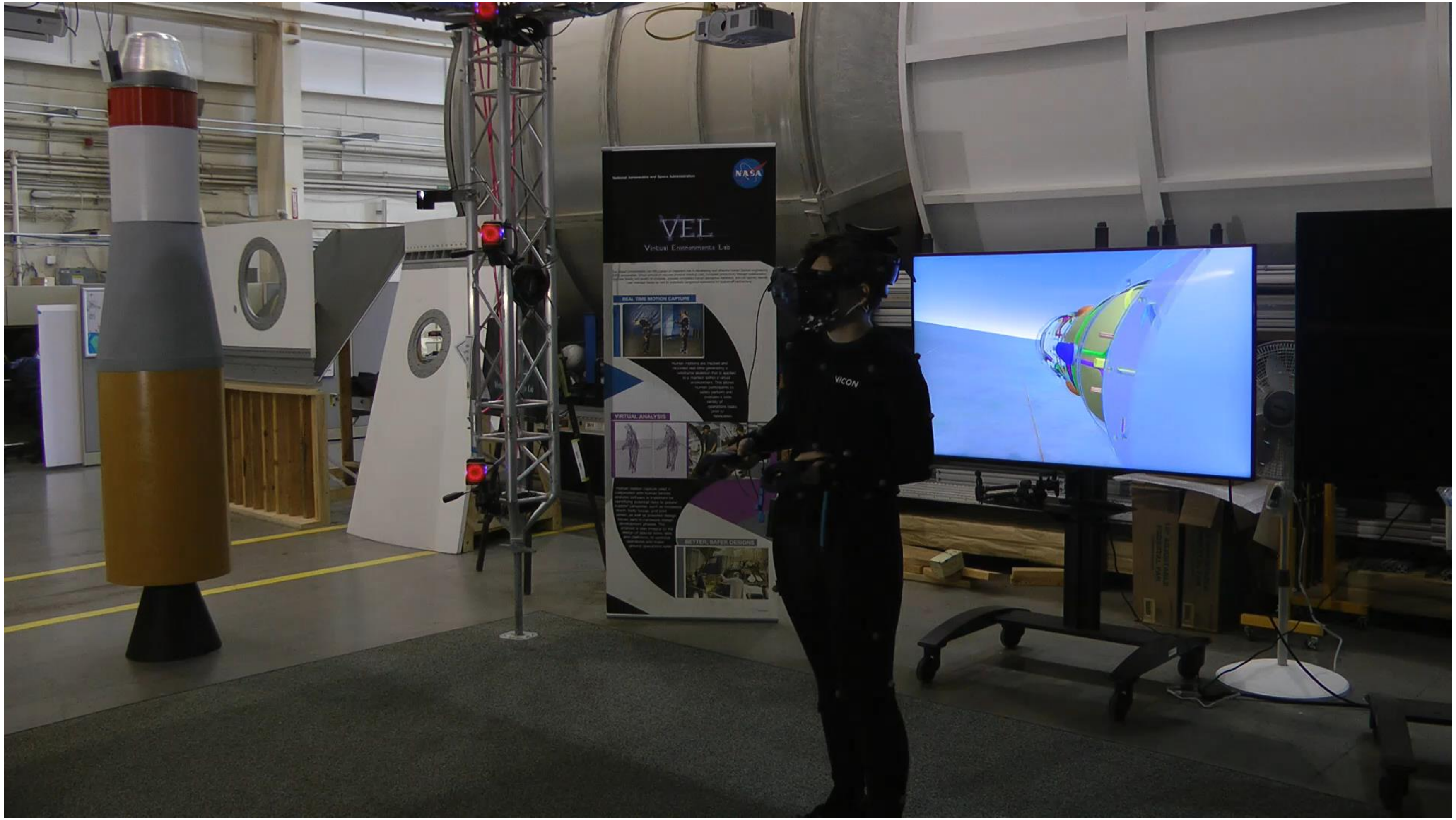
# Advantages of Working within VR

Human Factors &
Integrated Logistics Engineering

- Allows fast changing design layouts to be analyzed by various departments with minimal impact to cost or schedule.
- Allows for more conceptual work to be tested within a limited budget.
- Allows for VR use in early design cycles, saving time and budget.
- Resulting HFE analysis improves usability and safety for the technicians assembling the vehicle and the astronaut crew at launch.
- Collaborations with distant partners.

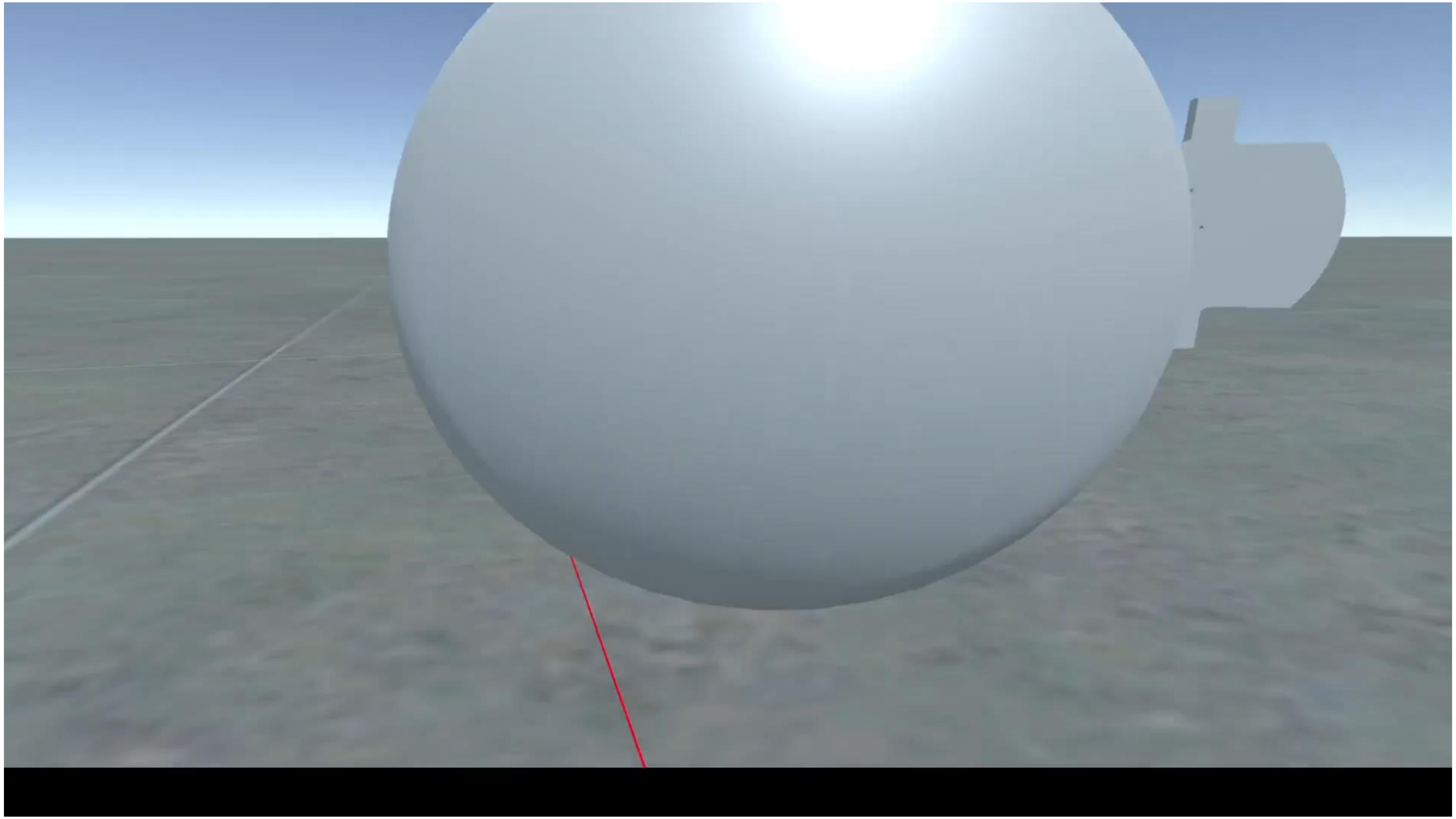
# 3rd person VEL Viewing





# 1st Person VR Viewing





# VEL Interstage Analyses

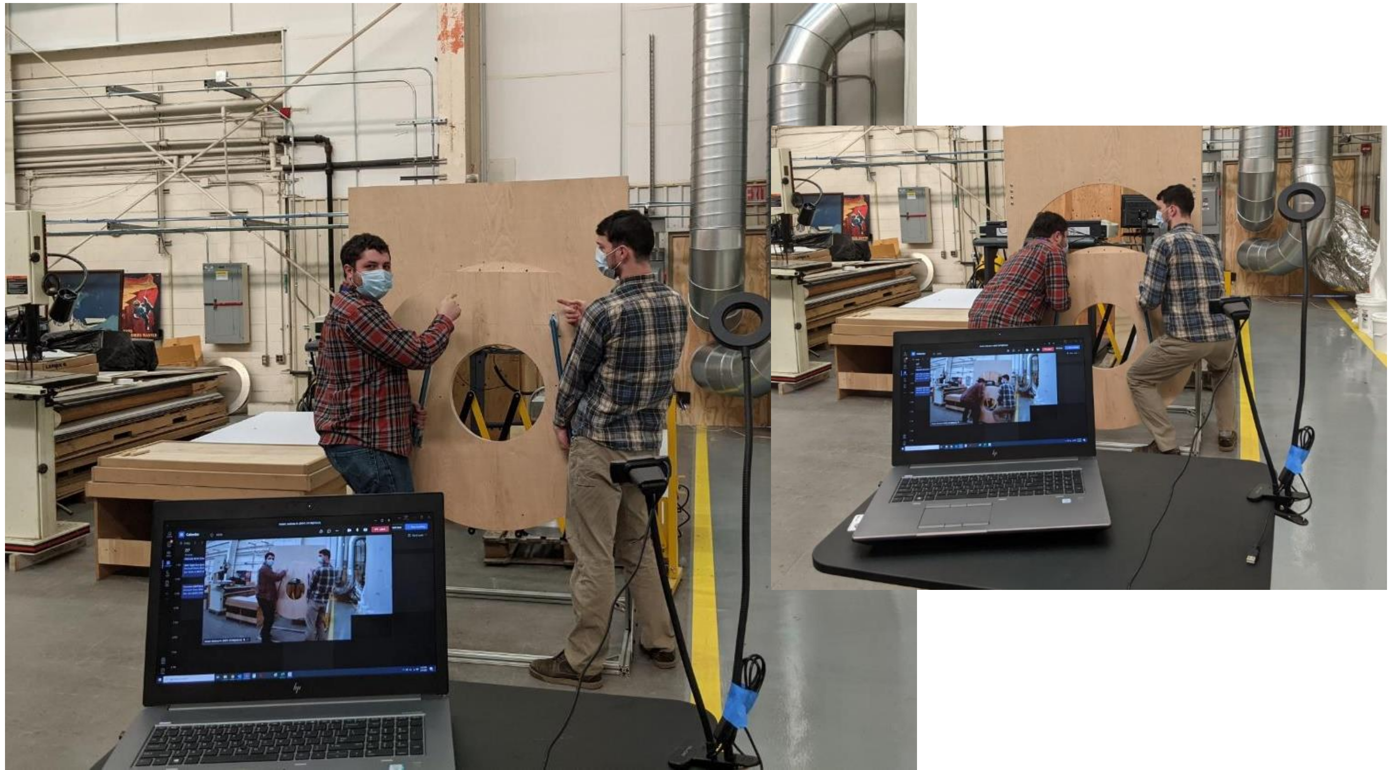


# Collaboration with Remote Partners



EV74 Human Factors collaborates with remote partners, via webcam and VR invitation, to participate in assessments, design evaluations and operations planning

- Example below showing collaboration with KSC EGS to optimize assembly and maintenance operations planning and provide ground crew training for the SLS vehicle.



# Fabrication Capabilities

Human Factors &
Integrated Logistics Engineering

In-house Mockup Shop capabilities enable the production of a wide variety of large and small scale mockups for projects, economically and rapidly

Mockup Shop in Building 4649

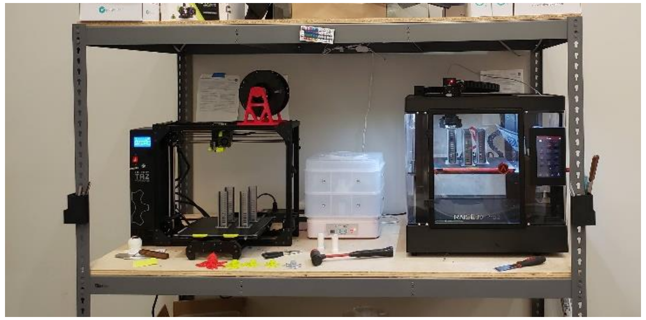
- 3 Axis Knee Mill
- Horizontal Metal Lathe
- Spindle Sander
- Compound Chop Saw
- CNC Router 4'x8' Bed
- Haas CNC 3 Axis Milling Center
- Table Saw
- Metal Brake
- Drill Press
- Metal Shear
- Wood Planer
- Sheet Roller

# 3-D Printing Capabilities



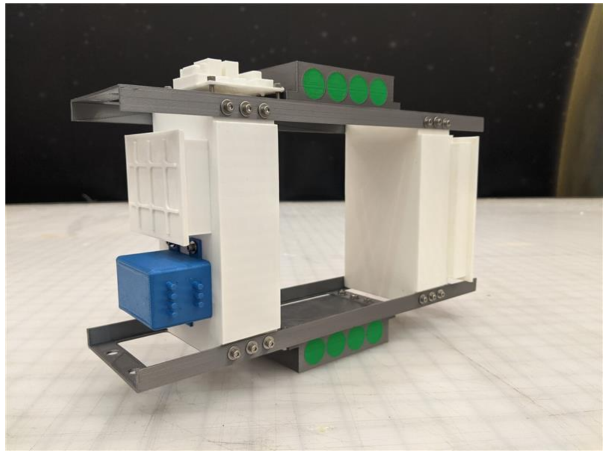
MAV SRM-1 to Vector Trunnion Pin

## 3D Printing Station

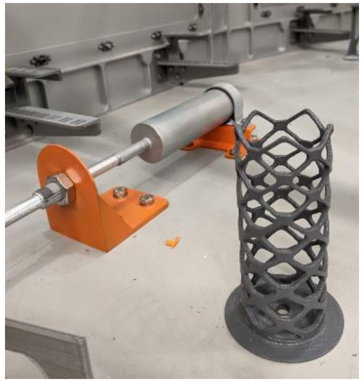


| Printer | Print Volume |
|---|---|
| LulzBot TAZ Workhorse | 280 mm x 280 mm x 285 mm (11.02 in x 11.02 in x 11.22 in) |
| Raise3D Pro2 | 305mm × 305mm × 300 mm (12 in × 12 in × 11.8 in) |

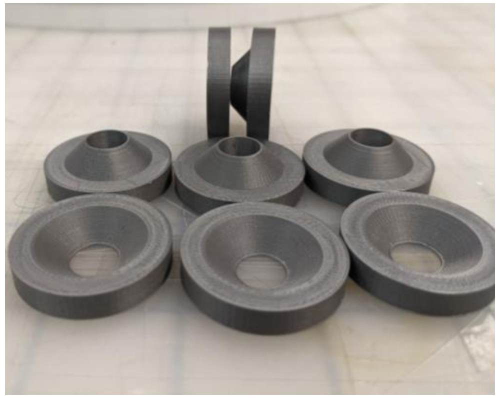
MAV Spin/Despin Motor



MAV Forward Structure Truss Assembly



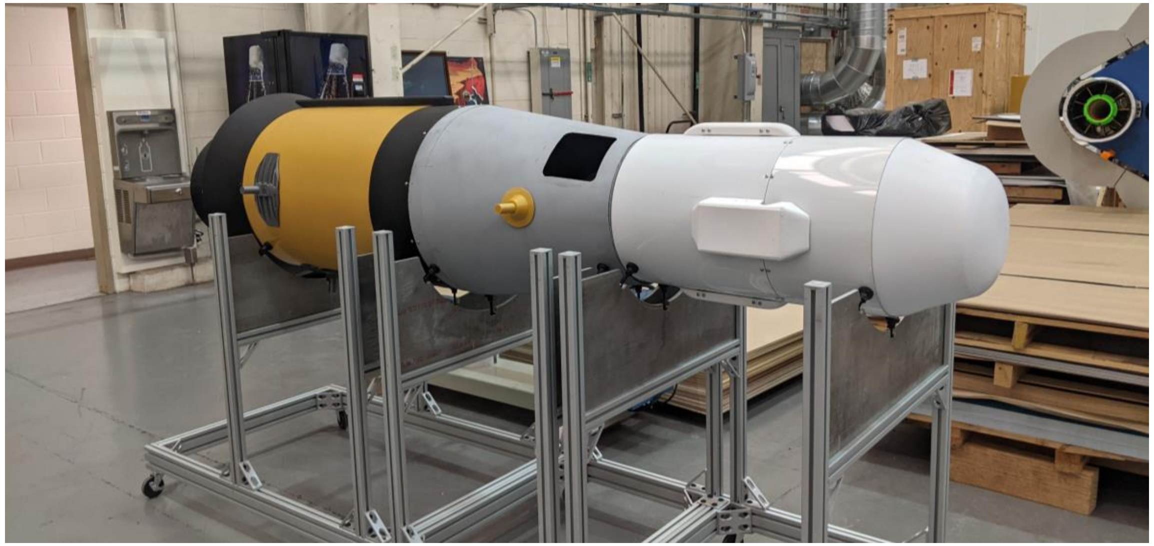
Examples of Detailed Printed Parts



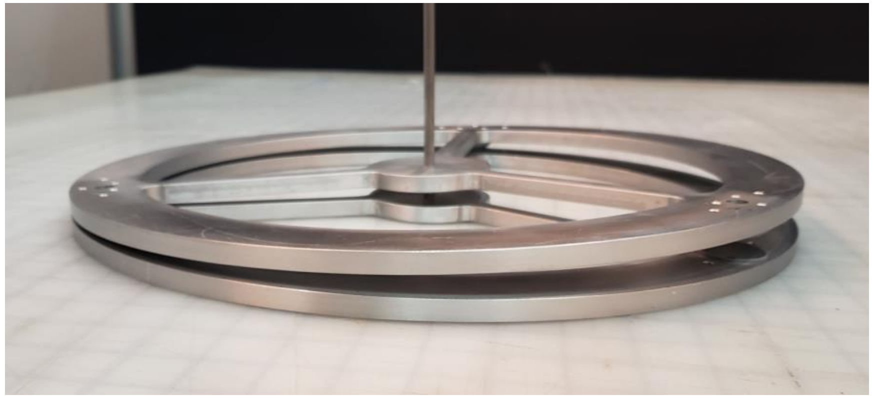
MAV Separation Pucks

# Full Scale Mockup Fabrication





MAV Volumetric
Mockup

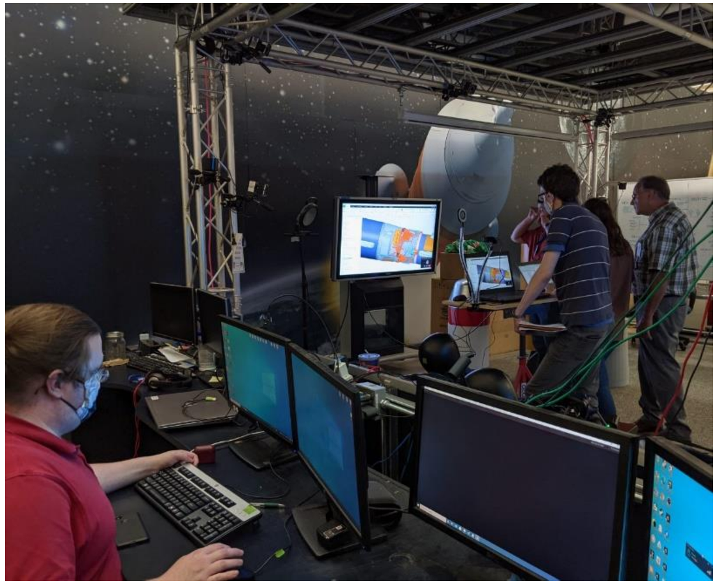


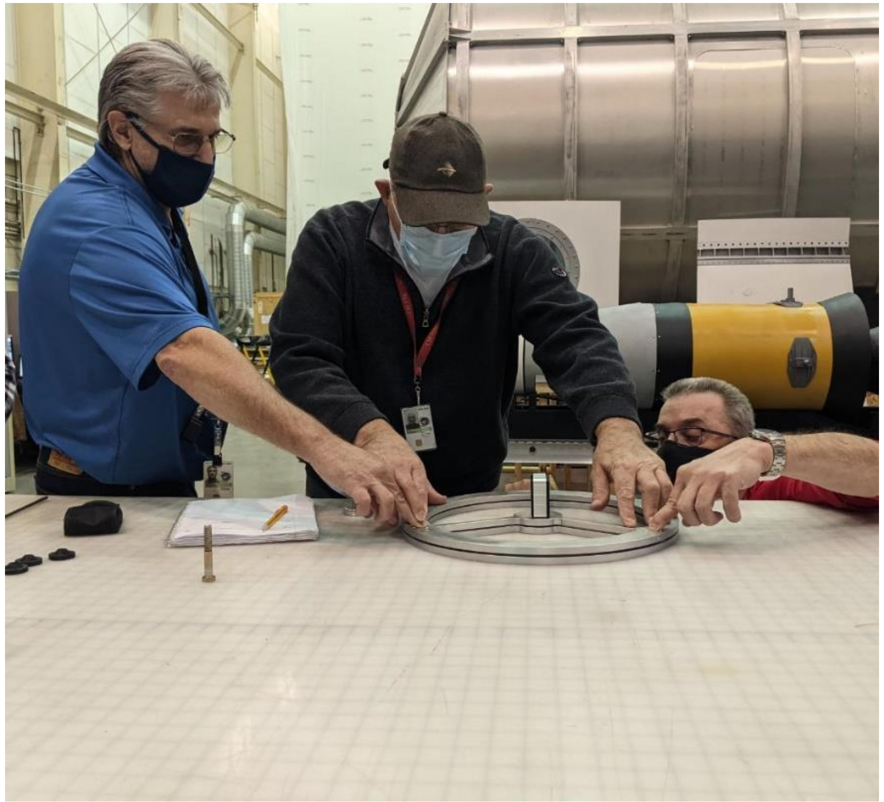
MAV Separation System
part-task mockup

MAV SRM2 with Nozzle and igniters

# EV74 Customer Utilization

Human Factors &
Integrated Logistics Engineering





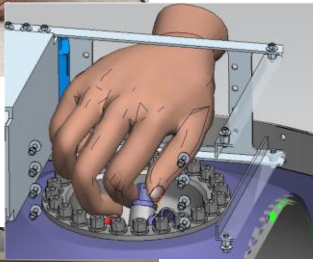
**Group Design Evaluation Hosted in HFE Facility**

# MAV Cost Effective HSI

Human Factors &
Integrated Logistics Engineering

## HSI Services Provided to MAV

- Evaluation of design in VR
- Full-scale volumetric mockup
- 3D print of design concepts for evaluation
- Part task physical mockups for evaluation
- HFE Analysis of designs/operations
- Design development support to disciplines
- ILSP Development



# MAV HSI at MSFC



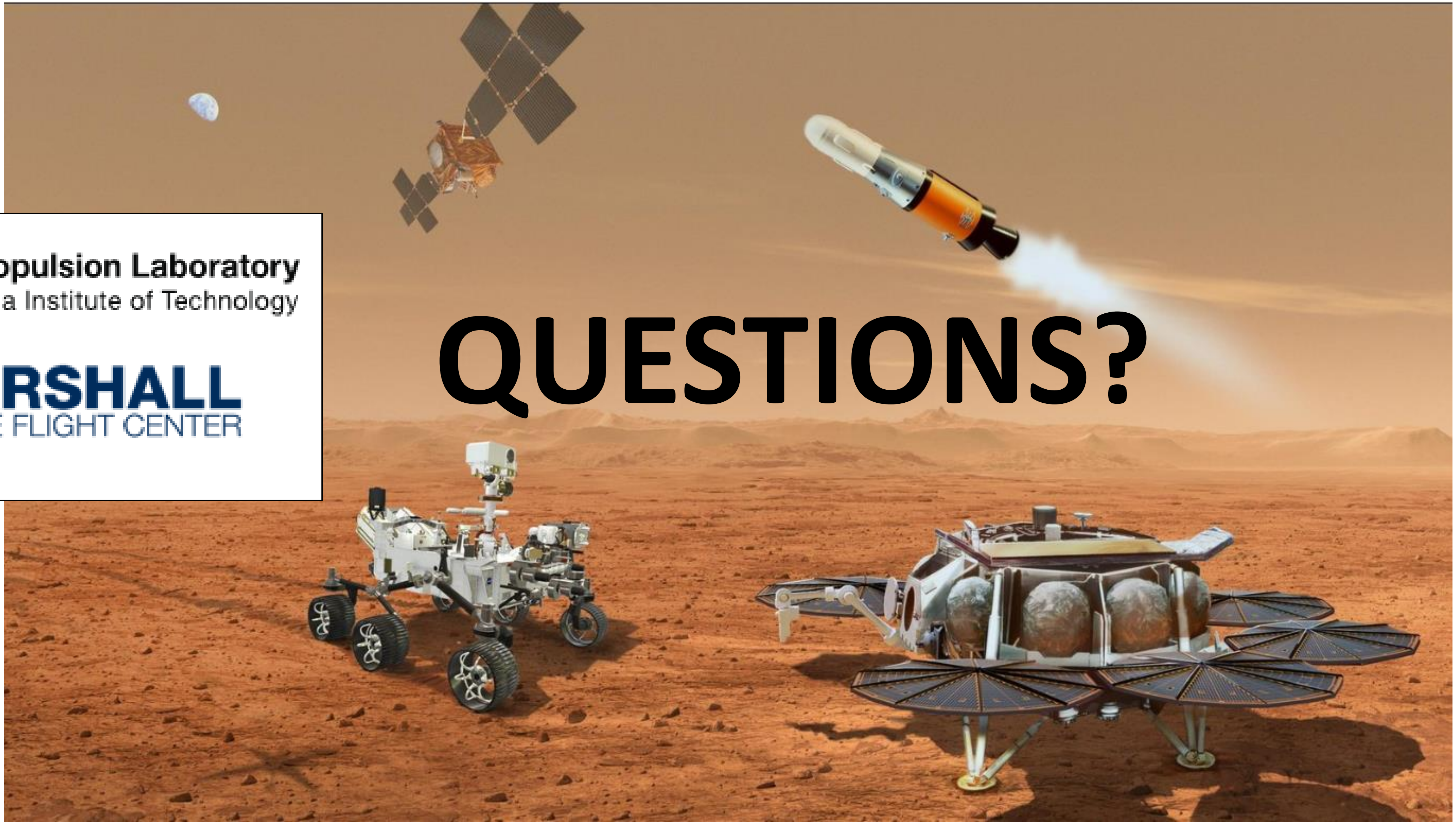
- Includes all domains, but HFE and ILS are primary concentrations
- HSI Plans do not have to be complex to add value
- Being flexible with the customer allows for the most growth potential with your HSI work
- Requirements as well as cost and schedule savings are big drivers for HSI plan
- Evolving as MAV evolves to meet immediate needs
- Insight and oversight roles to the contactor deliverables, providing evaluation and feedback for areas of concern

# Any Questions?

GEORGE C. MARSHALL SPACE FLIGHT CENTER
Human Factors &
Integrated Logistics Engineering

Jet Propulsion Laboratory
California Institute of Technology

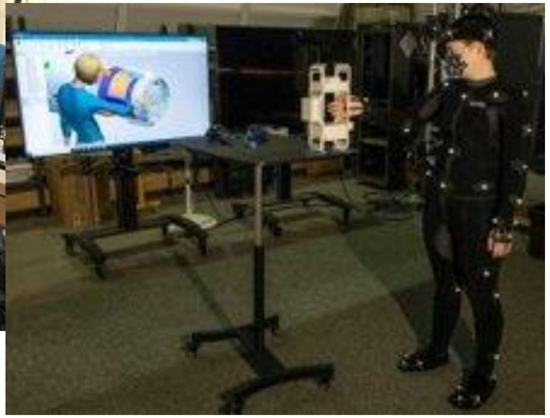
MARSHALL
SPACE FLIGHT CENTER



# BACKUP

# Building 4649

- EUS EqS
  - The EUS Equipment Shelf mockup is being disassembled and crated for shipment to MAF for reassembly and training.
  - Shipping will be complete by the end of June 2023.
- MAV
  - MAV has kept the team very busy with VEL analyses, HFE analyses, 3D print and manufacturing of specific design components, and mockup updates
- QD AR analyses
  - TE to develop Augmented Reality QD Analysis Tool
- SLS
  - Ongoing analyses for B1B with both VEL and Mockup Resources
- Athena
  - Mockup bid is in work. Potential VEL analyses and mockup.
- ECLSS Suitcase Habitat
  - Doing initial HFE analyses
  - Future 3D print and VEL analyses are being planned
- Working Surface Habitat (SH) and Transit Habitat (TH) Mockup Demonstrator builds with HP40
  - Served as SME on construction methodology, 4649 specific information, and purchased outfitting items as funds have become available.



# HFE Requirements

| | |
|---|---|
| Ground Support Personnel Accommodation | Worksites for MAV ground processing tasks shall be sized to accommodate, at minimum, 75 percent of the male and female combined population based on 1988 U.S. Army Anthropometry Survey (ANSUR) database (NATICK/TR-89/044). |
| Work Envelope Volumes | The MAV System shall provide the volume necessary for the ground support personnel to perform all ground processing tasks using the required tools and equipment. |
| Accommodating Protective Clothing and Equipment | The MAV system shall provide for ground processing by personnel wearing clothing and equipment appropriate to the environment during tasks. |
| Replaceable Items | The MAV system shall locate components so that ground processing tasks do not require the deintegration or demating of other systems or components to complete the task. |
| Hardware Interchangeablity | MAV system components handled during ground processing that are physically interchangeable shall be functionally interchangeable. |
| Connector Mismating | The MAV system shall have physical features that preclude mismating of connectors that are in close physical proximity during ground processing. |
| Incorrect Installation Prevention | MAV system hardware and equipment installed during ground processing shall be designed to prevent incorrect mounting or installation. |
| Captive Fasteners | MAV components included in ground processing tasks shall have captive fasteners. |
| Hazards Labeling | The MAV system shall provide labels to identify hazards to ground crew during ground processing. |
| Systems Accessibility | MAV system components, hardware, and/or equipment that require inspection or interaction during ground processing shall be accessible to the ground crew . |

| | |
|---|---|
| Task Feedback | Feedback shall be directly receivable to ground crew during MAV ground processing for tasks that are dependent on feedback. |
| Operational Consistency | The MAV system shall be designed for consistent operation across ground processing tasks. |
| Inadvertent Operation Prevention | The MAV system shall be designed to prevent inadvertent operation of controls during ground processing. |
| Component Grasp Areas | MAV components designed to be carried, supported, or removed and replaced during ground processing shall have grasp areas for ground crew if handling of component could result in damage to flight hardware or injury to ground crew. |
| Hardware Protection | MAV components that are susceptible to damage shall be protected from forces imposed by the ground support personnel during ground processing. |
| Readable Label Positioning | Labels and placards used during ground processing in the MAV system shall be located such that they are readable by the operator during use, considering ambient lighting conditions. |
| Lifting limits | For the MAV system, the weight limits in Table 3.2.5-1 shall be used as maximum values in determining the design weight of items requiring one person lifting with two hands during ground processing. |
| Sharp Edges | MAV hardware accessed during ground processing shall be designed to protect ground crews against injury from sharp edges. |
| Pinch Point Prevention | The MAV system shall be designed to protect ground personnel from injury due to pinch points during ground processing. |
| System Safing Controls | The MAV system shall allow ground personnel to safe the system before performing any ground processing operation. |
| Supplemental Systems (GSE) | The MAV system shall be designed to support any supplemental systems that are required to assist ground support personnel when an assigned task cannot reliably, safely, or effectively be performed by ground support personnel alone. |

# HSI Requirements Trace

## Mars Ascent Vehicle

# NPR 7120.5F



1. NASA Space Flight Program and Project Management Requirements
2. Effective Date: August 3, 2021
3. Changes Since revision E
4. Updates to program and project documentation and guidance include changes to the Appendix I table documentation and products developed during the life cycle. This includes the addition of the Human Systems Integration Plan, System Security Plan, Quality Assurance Surveillance Plan, Orbital Collision Avoidance Plan, and Performance Measurement Baseline and the deletion of the Education Plan, Information Technology Plan, and Product Data and Life Cycle Management Plan. In addition, this NPR adds reference to NASA/SP-2016-3424, NASA Project Planning and Control Handbook.

# 7120.5F Requirements Table

| Para # | NPR 7120.5 Requirement Statement | Require-ment Owner | Dele-gated | MD AA | CD | PM | Com-ply? | Justification | Approval |
|---|---|---|---|---|---|---|---|---|---|
| | [Required per NID 7120.132] | | | | | | | | |
| Table I-3 | 22. Human Systems Integration Plan [Baseline at SRR] [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO[1] | No | | | A | | | |
| 7 Table I-5 | 28. Human Systems Integration Plan [Baseline at SRR] [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO[1] | No | | | A | | | |
| | Table I-6 Single Project Program Milestone | | | | | | | | |
| Table I-7 | 28. Human Systems Integration Plan [Baseline at SRR] [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO[1] | No | | | A | | | |
| 2.2.8 | Projects, single-project programs (and other programs at | OCFO- | No | A | | A | | | |

# 7120.5F



**3.22 Human Systems Integration Plan**



Tightly coupled and single-project programs develop a Human Systems Integration (HSI) Plan that describes how human systems integration and human centered design will be integrated into the program design process and life cycle, including what types of human systems integration resources, tools, analysis, testing, and products will be employed/developed to ensure successful human systems integration, thereby reducing mission risk and total life-cycle or initial capability cost, while increasing overall safety. The plan also describes roles and responsibilities related to implementation of HSI. (See the NASA Human Systems Integration (HSI) Handbook, NASA/SP-20210010952, for additional information.)

## Table I-3 Tightly Coupled Program Plan Control Plans Maturity Matrix

| (See Appendix G Template for Control Plan Details.) | Product Owner/ Requirement or Best Practice | Formulation | | | Implementation | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | KDP 0 | | KDP I | | KDP II | | KDP III | KDP n |
| | | SRR | SDR | PDR | CDR | SIR | ORR | MRR/FRR | DR |
| per NID 7120.132] | | | | | | | | | |
| 22. Human Systems Integration Plan [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Baseline | Update | Update | Update | | | | |

[1] Review Plan should be baselined before the first review.

## Table I-5 Project Plan Control Plans Maturity Matrix

| (See Templates in Appendices G and H for Control Plan Details) | Product Owner/ Requirement or Best Practice | Pre-Phase A | Phase A KDP B | | Phase B KDP C | Phase C KDP D | | Phase D KDP E | | Phase E KDP F |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MCR | SRR | SDR/MDR | PDR | CDR | SIR | ORR | MRR/ FRR | DR |
| 27. Orbital Collision Avoidance Plan [Required per NID 7120.132] | OCE/R | | | | Baseline | Update | | | | |
| 28. Human Systems Integration Plan [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Preliminary | Baseline | Update | Update | Update | | | | |

## Table I-7 Single-Project Program Plan Control Plans Maturity Matrix

| (See Templates in Appendices G and H for Control Plan Details) | Product Owner/ Requirement or Best Practice | Pre-Phase A | Phase A KDP B | | Phase B KDP C | Phase C KDP D | | Phase D KDP E | | Phase E KDP F |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MCR | SRR | SDR/MDR | PDR | CDR | SIR | ORR | MRR/ FRR | DR |
| [Required per NID 7120.132] | | | | | | | | | | |
| 28. Human Systems Integration Plan [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Preliminary | Baseline | Update | Update | Update | | | | |

# MPR 7120.1 Revision H-1



1. Title: MSFC ENGINEERING AND PROGRAM/PROJECT MANAGEMENT REQUIREMENTS
2. Effective 2016-10-20
3. To establish the Center management procedural requirements for programs, projects, and activities to implement the provisions of Agency requirements in NPD 7120.4, NPR 7120.5, NPD 7120.6, NPR 7120.7 (NID 7120.99), NPR 7120.8, NPR 7120.10, NPR 7123.1, and NPR 7150.2.

# NPR 7120.5 Appendix I. Program and Project Products by Phase



### Table I-3 Tightly Coupled Program Plan Control Plans Maturity Matrix

| (See Appendix G Template for Control Plan Details.) | Product Owner/ Requirement or Best Practice | Formulation | | | Implementation | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | KDP 0 | | KDP I | KDP II | | KDP III | | KDP n |
| | | SRR | SDR | PDR | CDR | SIR | ORR | MRR/FRR | DR |
| 22. Human Systems Integration Plan [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Baseline | Update | Update | Update | | | | |

### Table I-5 Project Plan Control Plans Maturity Matrix

| (See Appendix H Template for Control Plan Details.) | Product Owner/ Requirement or Best Practice | Pre-Phase A | Phase A KDP B | | Phase B KDP C | Phase C KDP D | | Phase D KDP E | | Phase E KDP F |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MCR | SRR | SDR/MDR | PDR | CDR | SIR | ORR | MRR/ FRR | DR |
| 28. Human Systems Integration Pl an [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Preliminary | Baseline | Update | Update | Update | | | | |

### Table I-7 Single-Project Program Plan Control Plans Maturity Matrix

| (See Templates in Appendices G and H for Control Plan Details) | Product Owner/ Requirement or Best Practice | Pre-Phase A | Phase A KDP B | | Phase B KDP C | Phase C KDP D | | Phase D KDP E | | Phase E KDP F |
|---|---|---|---|---|---|---|---|---|---|---|
| | | MCR | SRR | SDR/MDR | PDR | CDR | SIR | ORR | MRR/ FRR | DR |
| 28. Human Systems Integration Plan [additional information in NASA/SP-20210010952 NASA HSI Handbook and NPR 7123.1] | OCE-OSMA-OCHMO/R | Preliminary | Baseline | Update | Update | Update | | | | |

# MAV-001 Project Plan



1. 1.4 Project Authority, Governance Structure, Management Structure, and Implementation Approach
2. “The authority, management approach, and governance structure of the MAV Project are derived from the Marshall Procedural Requirements (MPR) document 7120.1, “MSFC Engineering and Program/Project Management Requirements.” MPR 7120.1 establishes the center management procedural requirements for programs, projects, and activities to implement the provisions of Agency requirements in NASA Procedural Directive (NPD) 7120.4, NASA Procedural Requirement (NPR) 7120.5, NPD 7120.6, NPR 7120.7 (NASA Interim Directive (NID) 7120.99), NPR 7120.8, NPR 7120.10, NPR 7123.1, and NPR 7150.2.”