# NASA-Johnson Space Center

## Engineering Directorate Overview
## And
## L-8 Initiative

**Montgomery Goforth**

Strategic Pursuits and Partnerships

# Johnson Space Center

JSC is the heart of . . .
the operations,
scientific,
and engineering community
that leads at the frontier of human
space exploration,
where technical challenges are most
daunting and risks are highest

Main Site: Houston, TX
Civil Servants ~3000
On/near site ~10,000

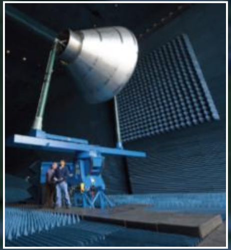
Additional Facilities:
White Sands, NM
Neutral Buoyancy Lab
Ellington Field, TX

**ENGINEERING DIRECTORATE**

Kevin Window, Director
TBD, Deputy Director
Mary Beth Schwartz, Associate Director
Monte Goforth, Strategic Pursuits and Partnerships

Crew & Thermal Systems

Aeroscience & Flight Mechanics



Avionic Systems

Propulsion & Power

Structural Engineering


Software, Robotics, & Simulation

JSC ENGINEERING NASA

**TECHNICAL INTEGRATION OFFICE**

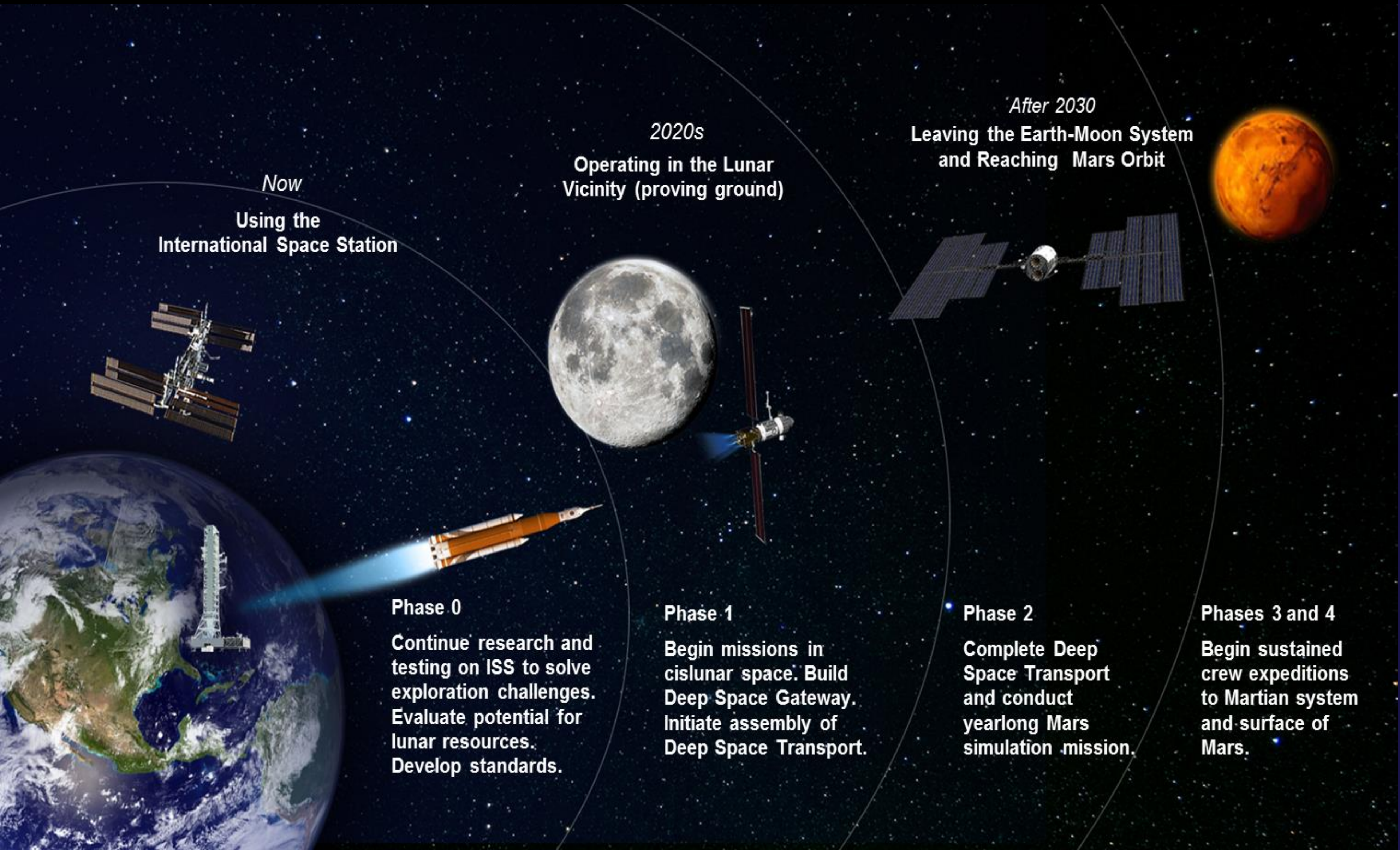
**PROJECT MANAGEMENT & BUSINESS INTEGRATION OFFICE**

## Engineering Main Roles

- Technical Authority
- Systems Management
- GFE Development
- In-line Spacecraft Development
- Test & Analysis
- Independent Verification & Validation

# EXPANDING HUMAN PRESENCE IN PARTNERSHIP

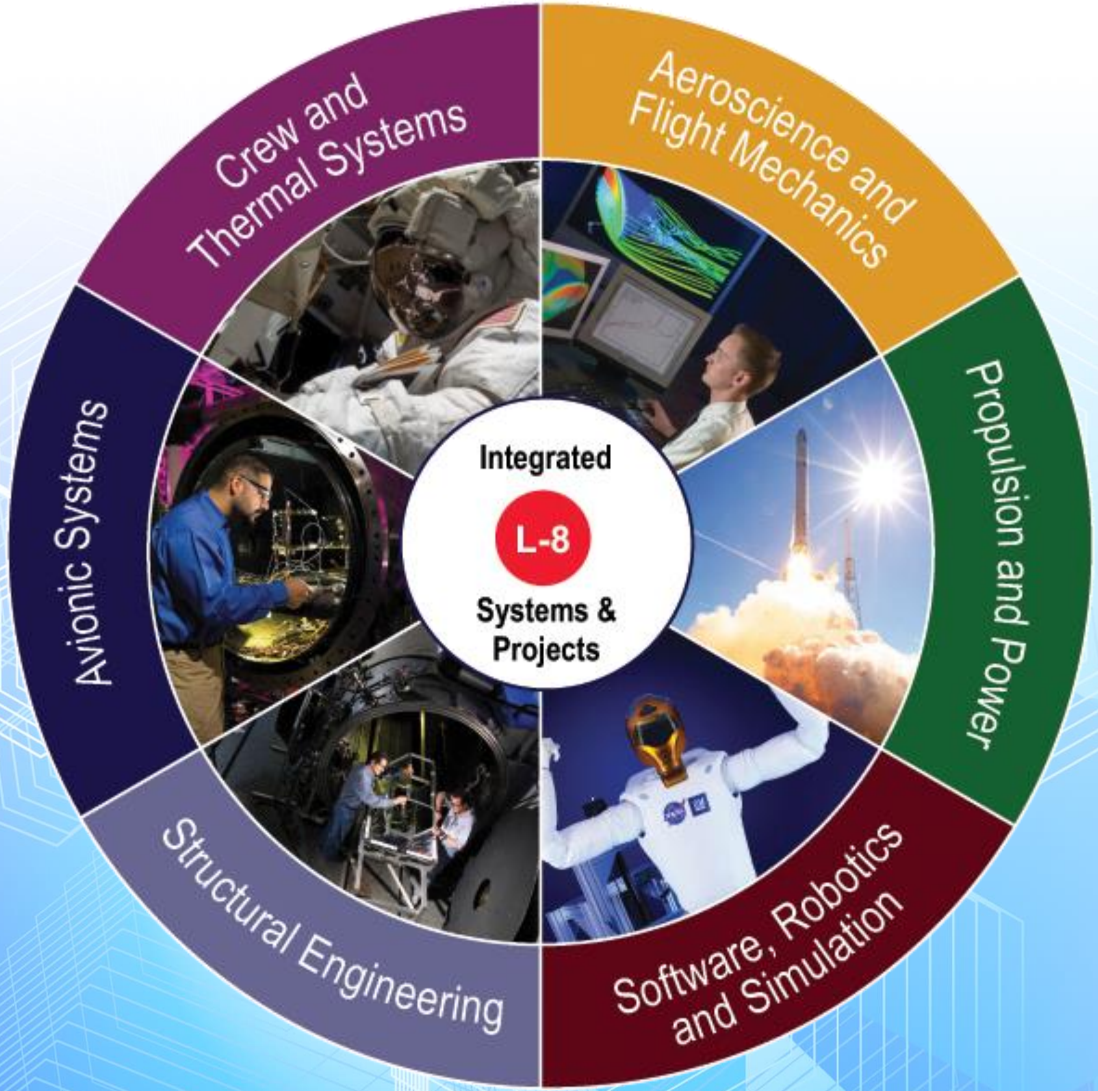
*CREATING ECONOMIC OPPORTUNITIES, ADVANCING TECHNOLOGIES, AND ENABLING DISCOVERY*




## JSC Engineering Priorities

1. Enhance ISS: Enhanced missions and systems reliability per ISS customer needs
2. Accelerate Orion: Safe, successful, affordable, and ahead of schedule
3. Enable commercial crew success
4. Human Spaceflight (HSF) exploration systems development
   - Technology required to enable exploration beyond LEO
   - System and subsystem development for beyond LEO HSF exploration

# EA's internal goal for Exploration




- EA has clear priorities and defined activities associated with the ISS, Orion, and Commercial Crew programs.
- We want to sharpen our focus on exploration-related work
- We want to ensure that HSF technologies are ready to take Humans to Mars in the 2030s.
  - Various Roadmaps define the needed technologies
  - We are attempting to define our activities and dependencies
- Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025
  - Develop and Mature the technologies and systems needed
  - Develop and Mature the personnel needed

# JSC Engineering's Domain Implementation Plan

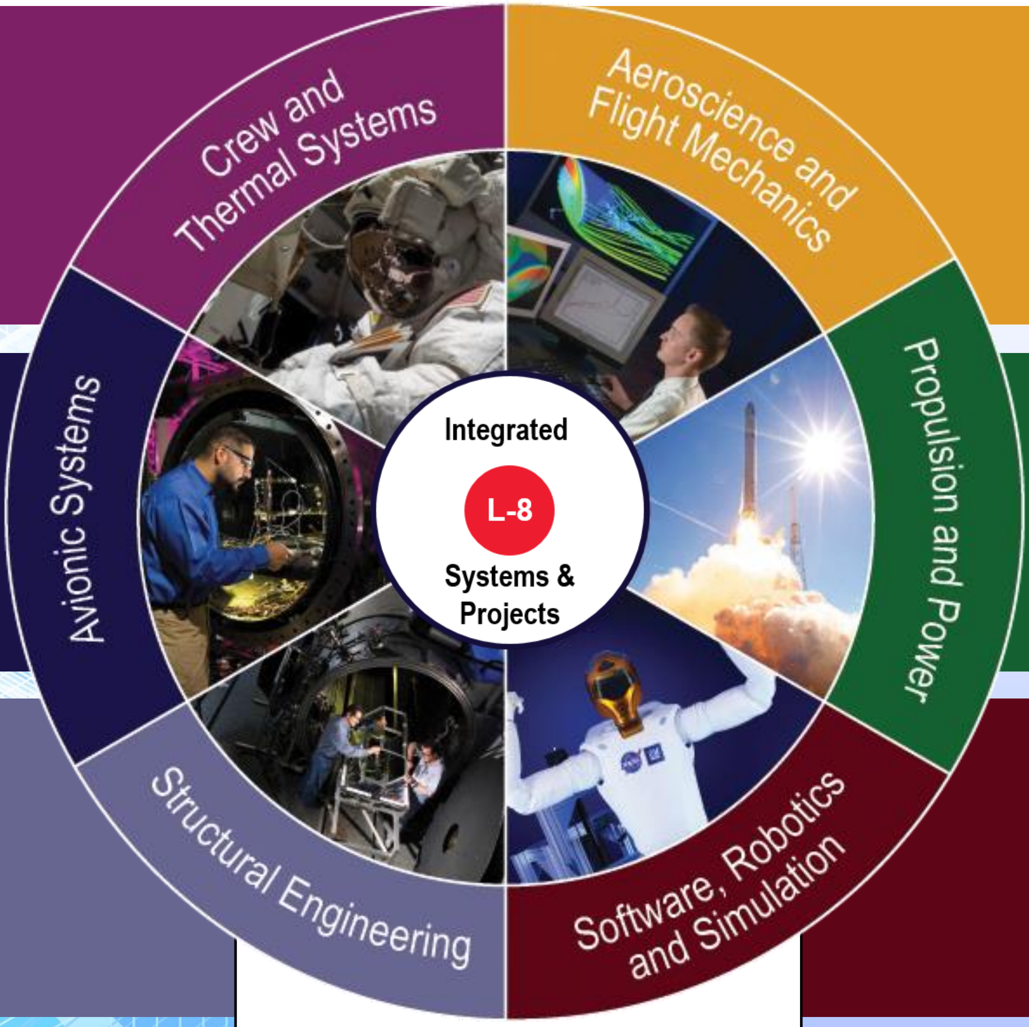
*JSC Engineering: HSF Exploration Systems Development*

- Life Support
- Active Thermal Control
- EVA
- Habitation Systems

- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Deep Space GN&C

- Human System Interfaces
- Wireless & Communication Systems
- Command & Data Handling
- Radiation & EEE Parts

- Reliable Pyrotechnics
- Integrated Propulsion, Power, & ISRU
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

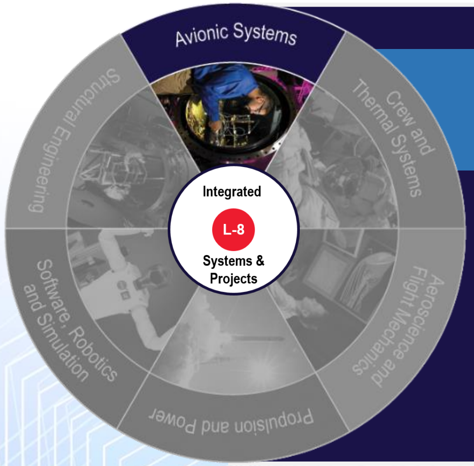



- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Vehicle Environments

- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

AA-2 | iPAS | HESTIA | Cis-Lunar

# Avionics Systems Domain Implementation Plan Decomposition Example




- Wireless & Communication Systems
- Command & Data Handling
- Human System Interfaces
- Radiation & EEE Parts

<u>Areas of Emphasis (AOEs):</u>

- RFID ALM
- RFID Sensing
- Delay Tolerant Networking (DTN)
- Mesh Networking
- Wireless Development Flight Instrumentation
- Proximity Communications
- Reconfigurable/Software defined radio
- Innovations for C&T testing and validation
- Innovative applications of RF technology
- Proximity antenna technologies
- Optical Communication

<u>Pathstones:</u>

Gap • RF Interrogator development
Gap • Fabric antenna development
Gap • System integration and modularization

**Potential for Partnership**

A SpaceCom 2016 Collaboration Opportunity
“L-8: RFID technology and sensor interrogators for wireless sensing/telemetry “
– Ray Wagner

Example

Potential Gap Closure Partnerships with Academia

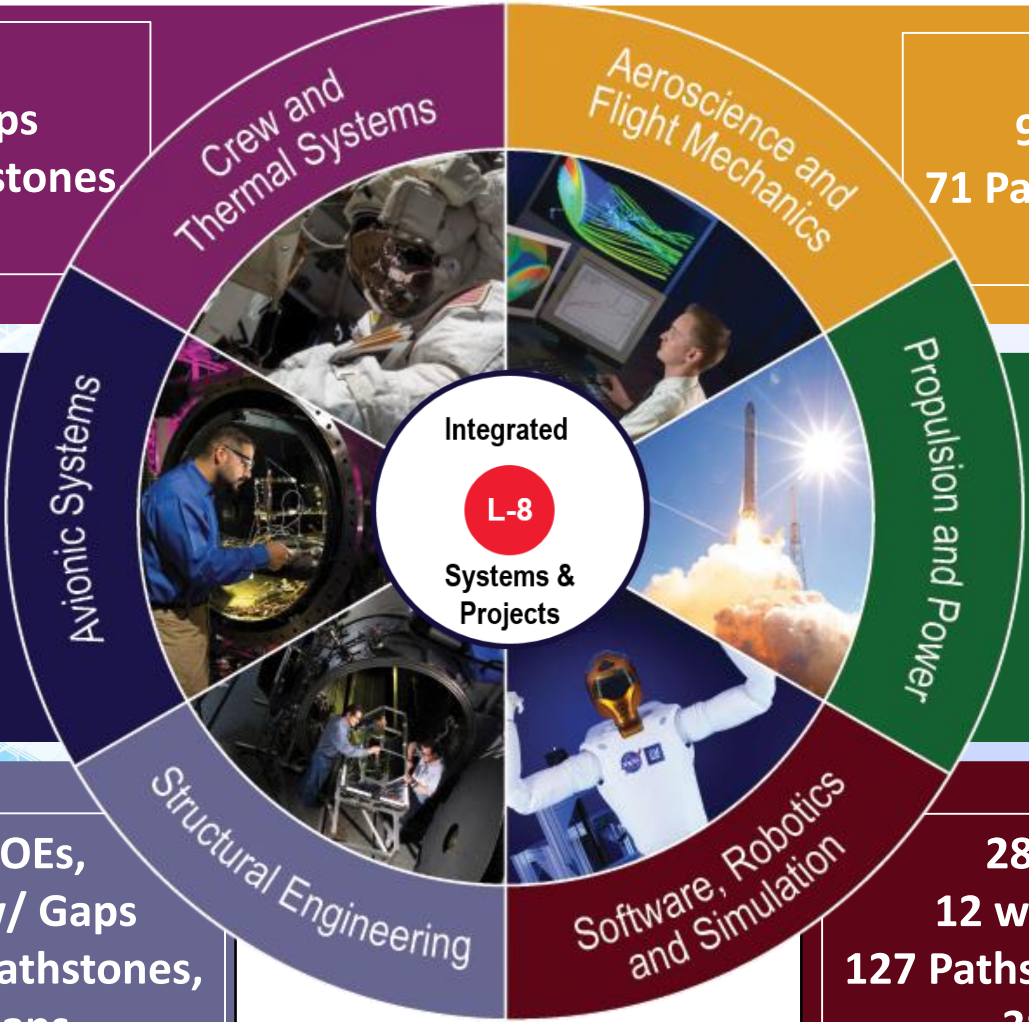
Example

# EA Domain Implementation Plan Overview

*JSC Engineering: HSF Exploration Systems Development*

- Life Support
- Active Thermal Control
- EVA
- Habitation Systems

**34 AOEs,**
**27 w/ Gaps**
**166 Pathstones**
**48 Gaps**




**11 AOEs,**
**9 w/ Gaps**
**71 Pathstones,**
**36 Gaps**

- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Deep Space GN&C

- Human System Interfaces
- Wireless & Communication Systems
- Command & Data Handling
- Radiation & EEE Parts

**28 AOEs, 19 w/ Gaps**
**116 Pathstones, 63 Gaps**

- Reliable Pyrotechnics
- Integrated Propulsion, Power, & ISRU
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

**14 AOEs, 9 w/ Gaps**
**66 Pathstones, 18 Gaps**

- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Vehicle Environments

**20 AOEs,**
**19 w/ Gaps**
**86 Pathstones,**
**58 Gaps**

AA-2 | iPAS | HESTIA | Cis-Lunar

**28 AOEs,**
**12 w/ Gaps**
**127 Pathstones,**
**38 Gaps**

- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

# FY 2016 IRAD Investments Tied to L-8

*JSC Engineering: HSF Exploration Systems Development*

Shape-Morphing Adaptive Radiator Technology (SMART) – L. Erickson

ISS Capillary Development (CapDev) Test Bed - Sargusingh

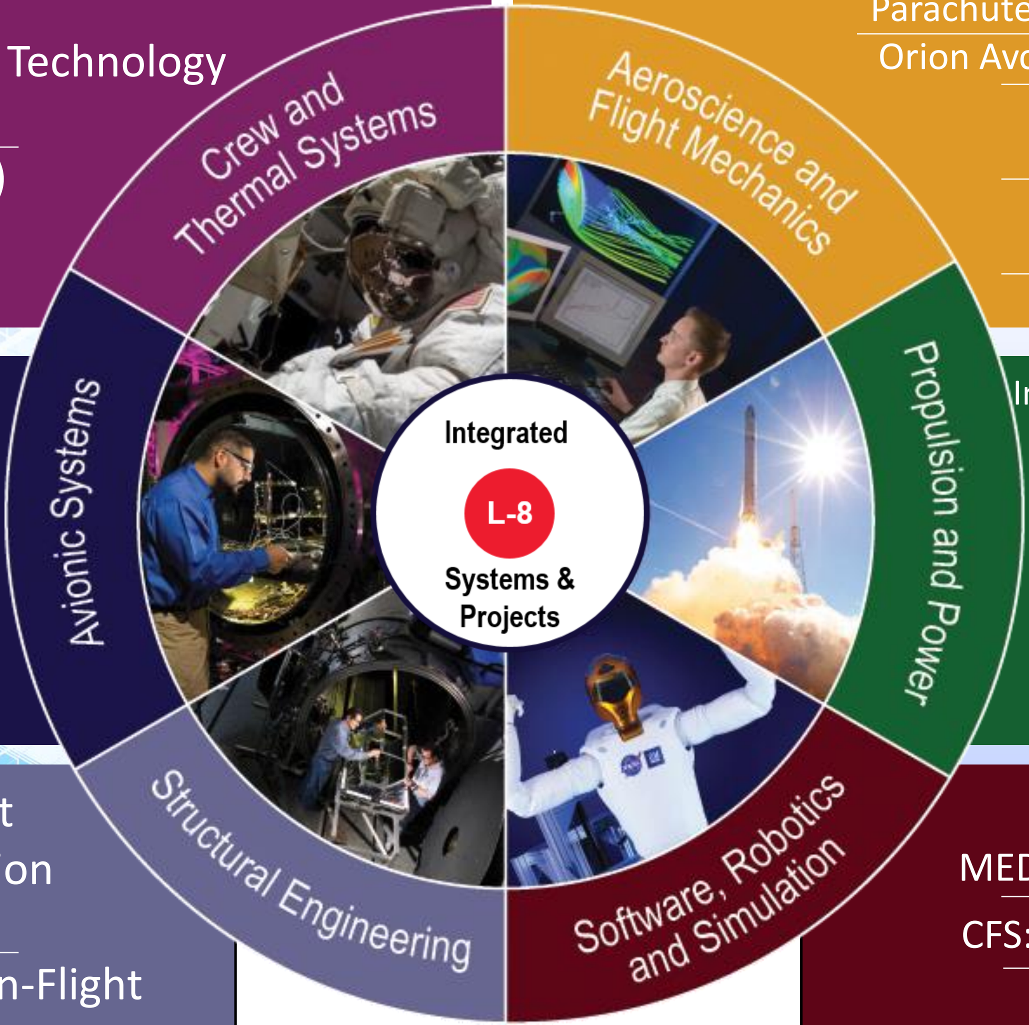
The Modular Wearable Architecture: Lowering the Human-System Barrier - Simon

Personal CO2 Monitor – Simon

Software Graphics Processing Unit (sGPU): Solving the Visual Display Problem for BEO Missions – McCabe

Novel Passive Thermal Management Systems for Future Human Exploration – Alvarez-Hernandez

Novel Passive Thermal Technology In-Flight Demonstration – Alvarez-Hernandez




AA-2 | iPAS | HESTIA | Morpheus

Parachute Canopy Instrumentation Package - Alshahin

Orion Avcoat Material Heat Shield Flight Test - Salazar

Visual Odometry for Autonomous Deep-Space Navigation – Robinson

Advanced Analytic Tools & Capabilities for Aerosciences – Kirk

Mid L/D Mars EDL Pathfinder – Campbell

Integrated Lox/LCH4: A Unifying Technology for Future Exploration (Phase II Work) – B. Banker

Solid State Thermionics Power – J. George

Regenerative Gas Dryer for Integrates ISRU Systems – A. Paz

LOX/LCH4 Propulsion Test in Space Environment – Morehead

Q-Thruster Work

MED-2 Exercise Device Operations – Zumbado

CFS: Human Spaceflight Product Line – Prokop

HESTIA Sim Support – Bielski

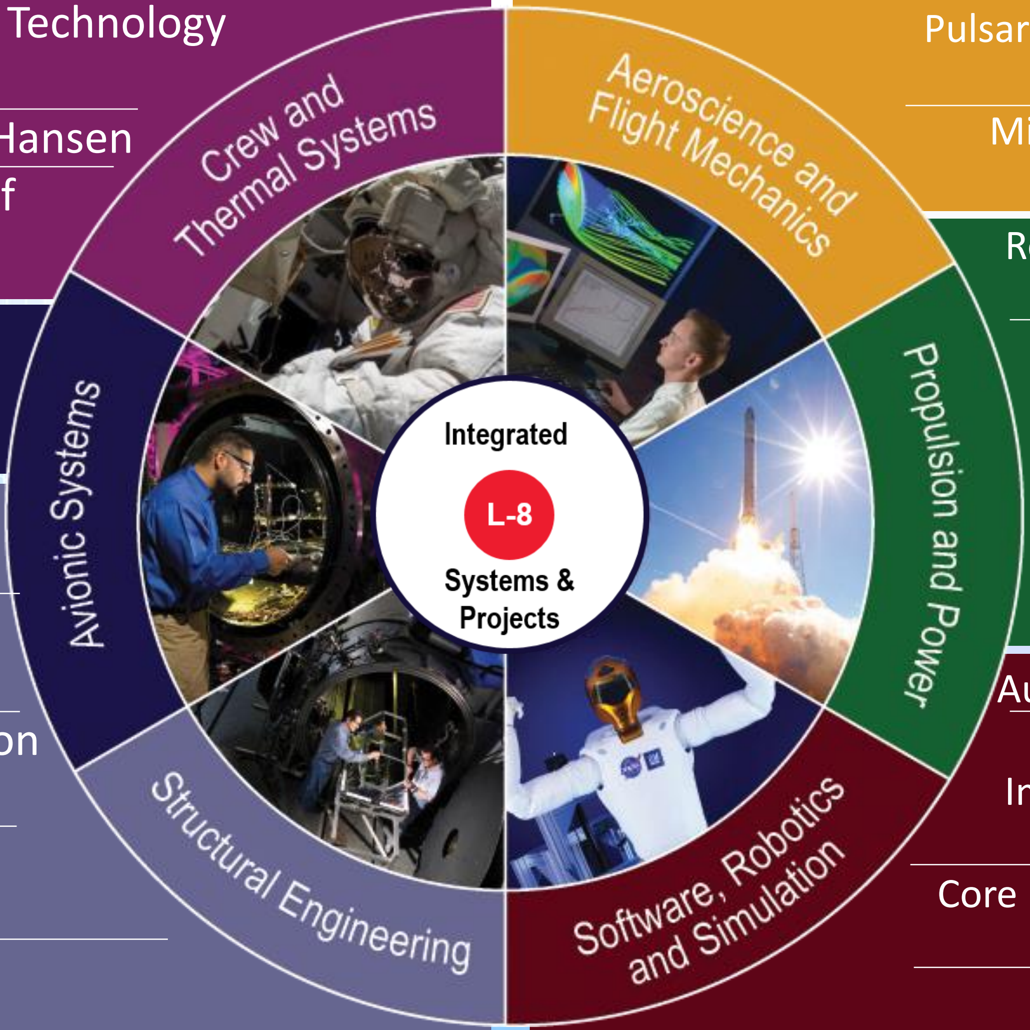
# FY 2017 IRAD Investments Tied to L-8

*JSC Engineering: HSF Exploration Systems Development*

- Shape-Morphing Adaptive Radiator Technology (SMART) II – Erickson
- Laser Processed Heat Exchangers - Hansen
- A Low Power, Solid State, Method of Oxygen Supply - Graf

- Magnetic Radiation Shielding for Human Space Exploration - Arndt

- Orion Heat Shield Spectrometer – Holland
- Entry Vehicle (Dragon) On Demand Instrumentation - Wells & Bouslog
- Advanced Heat Shield Instrumentation Flight Test - Wells
- Charring Ablator Response (CHAR) Sublimation - Remark
- Aluminum Orbital Arc Weld Development - Luna
- Inflatable Airlock EVA Interface - Litteken




- Cis-Lunar Habitat: Model Based Engineering - Othon

- Pulsar Navigation for Crewed Exploration of the Solar System - D'Souza
- Mid-L/D Ballistic Range Aerodynamics Test - Sostaric

- Retiring the Side Wall Rupture Risk with Li-Ion – Darcy
- SMR/SOFC System Integration for LOx/LCH4/ISRU – Mwara
- Cubesat Q-Thruster Technology for Exploration – White
- Flat H Redundant Frangible Joint (RFJ) - Brown

- Augmented Reality Authoring Tool - Wang
- Fatigue Reduction and Dexterity Improvements via Space Suit Glove Grasp Strength Augmentation - Rogers
- Core Flight Software (CFS) Human Spaceflight Product Line (CITO) - Prokop
- Integrated System Demonstration for Spacecraft Autonomy (Basics) – Badger
- Cis-Lunar Habitat: Simulation - Crues

Draft
10/16/17

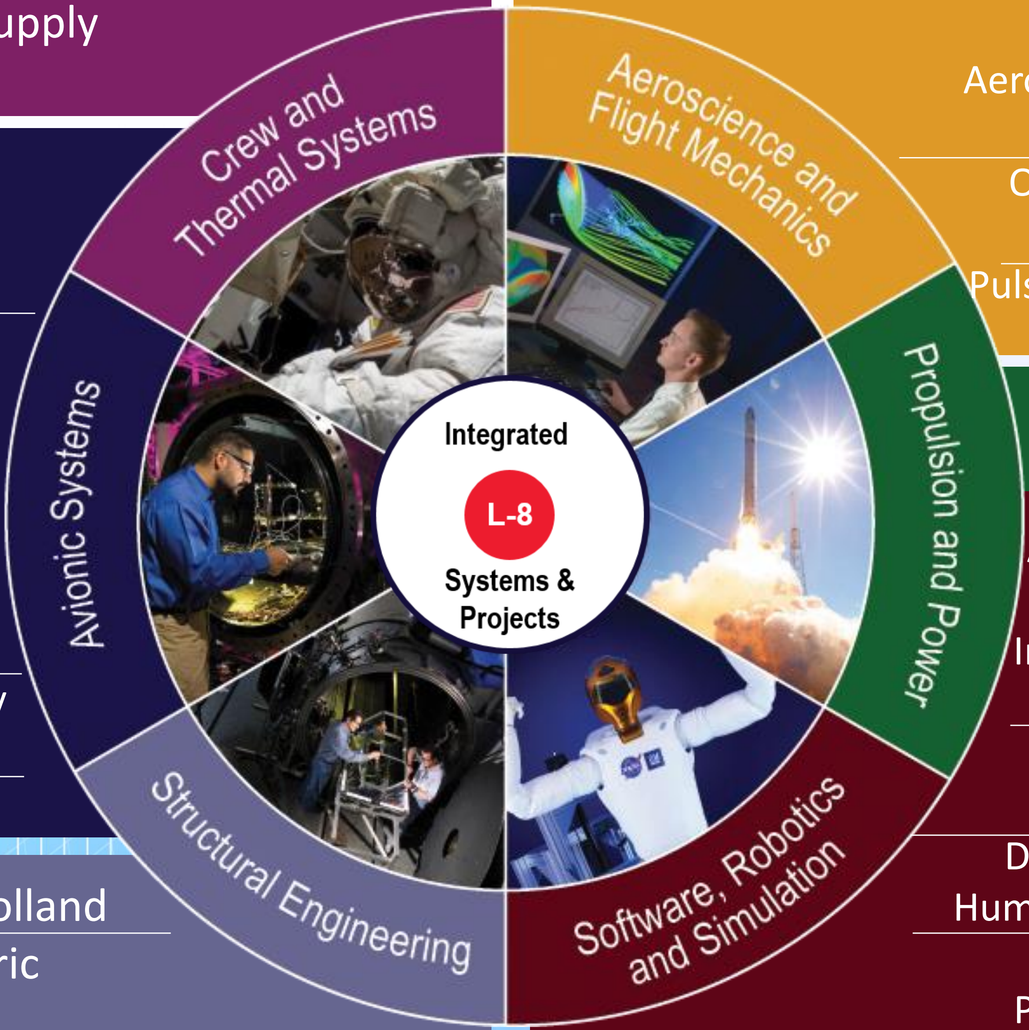
# FY 2018 IRAD Investments Tied to L-8

*JSC Engineering: HSF Exploration Systems Development*

High Pressure High Purity Oxygen Supply (HPHP-O2) - Broerman

- Application of JSC Radiation Tolerant Electronics to High Speed Data Links – Shuler
- Chisel: Rapid Plug and Play Data Acquisition and UI Development – Lee
- Inexpensive Radiation Hardened MISL Microcontroller Board Development Enabling IoT in Space – Harnett
- Multi-sensor Wearables for ISS and Exploration – Bautista
- Ultra Long-Lived Autonomous Air Quality Sensing – Wagner
- SpX Heat Shield Instrumentation - Wells

- Orion Heat Shield Spectrometer – Holland
- Flexible Printed Strain Gages for Fabric Structures – Litteken
- 3D Printing Heat Shields - Bouslog




Seeker: Robotic External Free Flyer - Askew

- Wind Tunnel Test of Rigid Mid-L/D Aerocapture/ Entry Vehicle for Human Class Mars Missions – Daum
- Onboard Adaptive Safe Site Identification System – Restrepo
- Pulsar Navigation for Crewed Exploration of the Solar System – D'Souza

450 WH/kg Li Metal Rechargeable Battery – Darcy

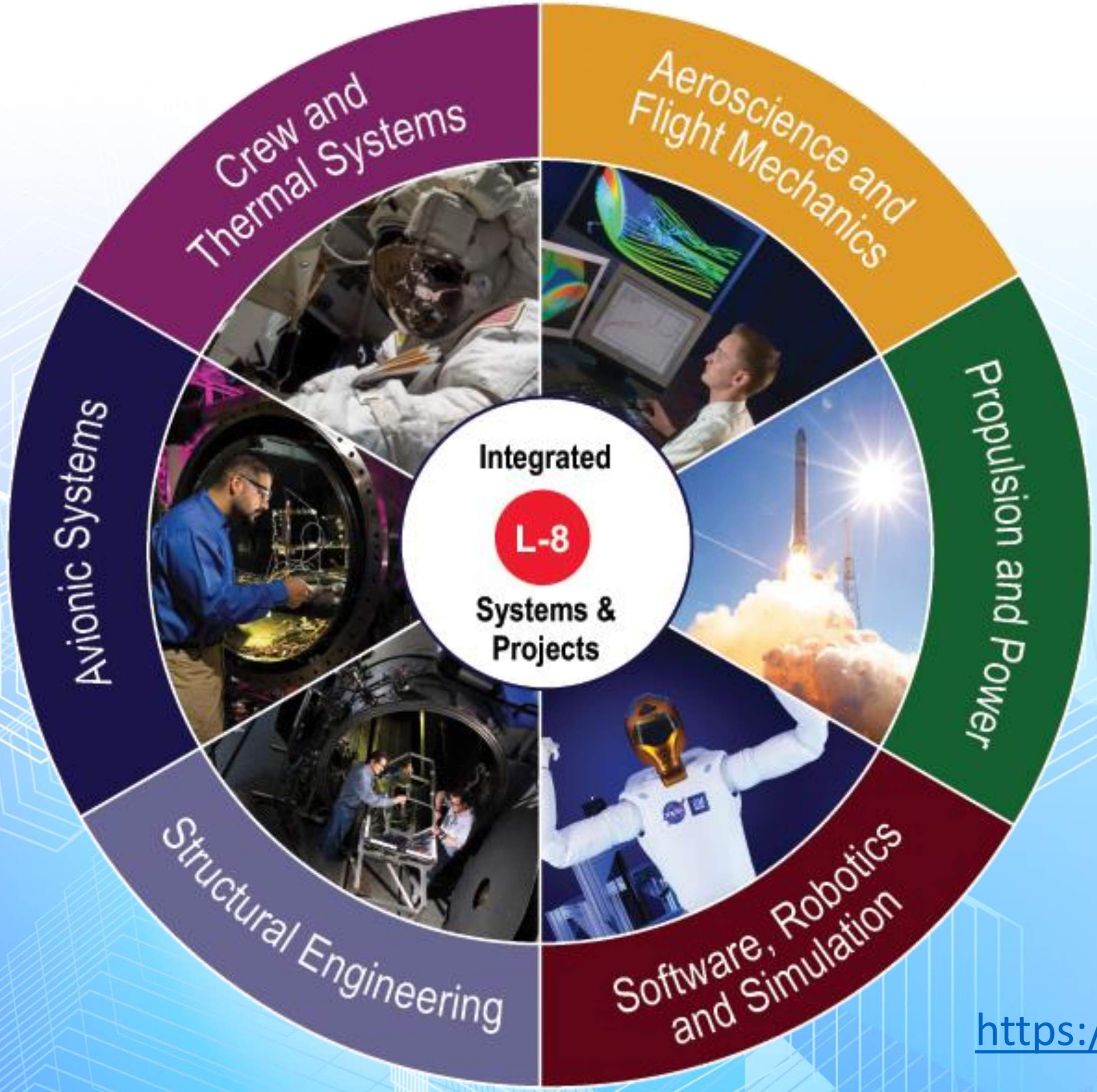
- Autonomous Spacecraft Management for Dormant Habitats – Badger
- Immersive Design and Engineering System (IDES) – Noyes
- Eyetracking Analytics Platform for Hybrid Reality – Noyes
- Digital Astronaut Upper body Modeling for Human Countermeasures Analyses – Quiocho
- Formal Evaluation of Knee Dynamometer Prototype for Advancement Toward Space Flight - Herrera

# We are looking for Partners

- Our L-8 efforts have identified a lot of problems to be solved before we can go to Mars, and we need partnerships to help solve them.

- Partnerships with NASA JSC can take many forms:
  - Partner Technology → NASA Evaluation/Test → Increased Knowledge
  - Partner Need → NASA-unique technology/capability/facility → Desired Results
  - Similar Problems, Different Capabilities → Technology Collaboration → Solution
  - NASA Technology → Partner adapts to terrestrial need → NASA harvests improvements
  - Partner Technology → NASA Adapts to Spaceflight Needs → Partner harvests improvements

# JSC Engineering: HSF Exploration Systems Development



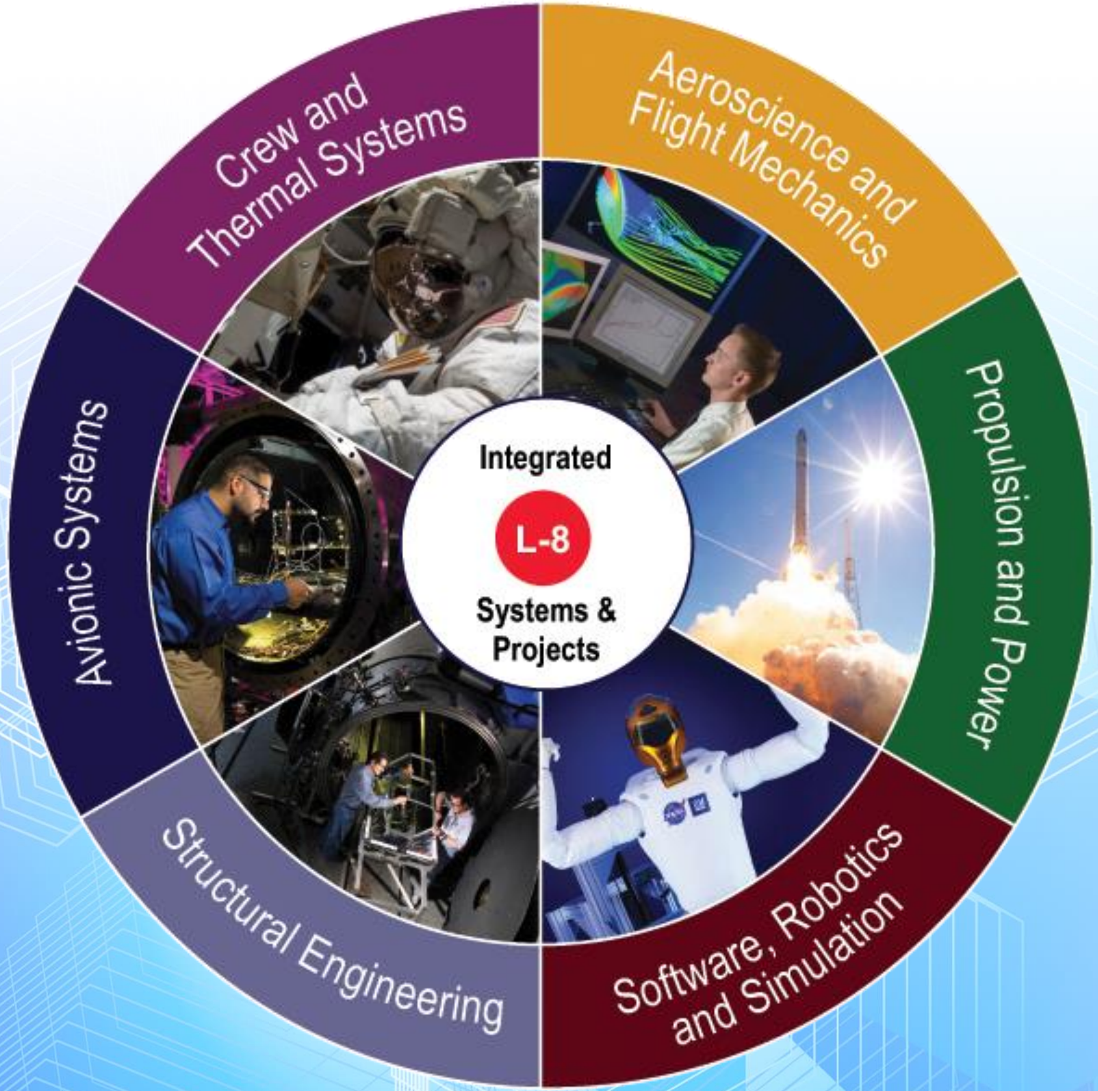

- We want to ensure that HSF technologies are ready to take Humans to Mars in the 2030s.
- Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025

- If you're interested let us know at:

https://nasajsc.secure.force.com/ConnectForm

# Backup Information

*JSC Engineering: HSF Exploration Systems Development*




- Special Report(s)
- EA Challenges & Opportunities
- 2016 IRAD Investments
- 2017 IRAD Investments
- 2018 IRAD Investments

# EA Challenges & Opportunities

*JSC Engineering: HSF Exploration Systems Development*

Advanced Concepts for O2 Concentration and storage – Graf

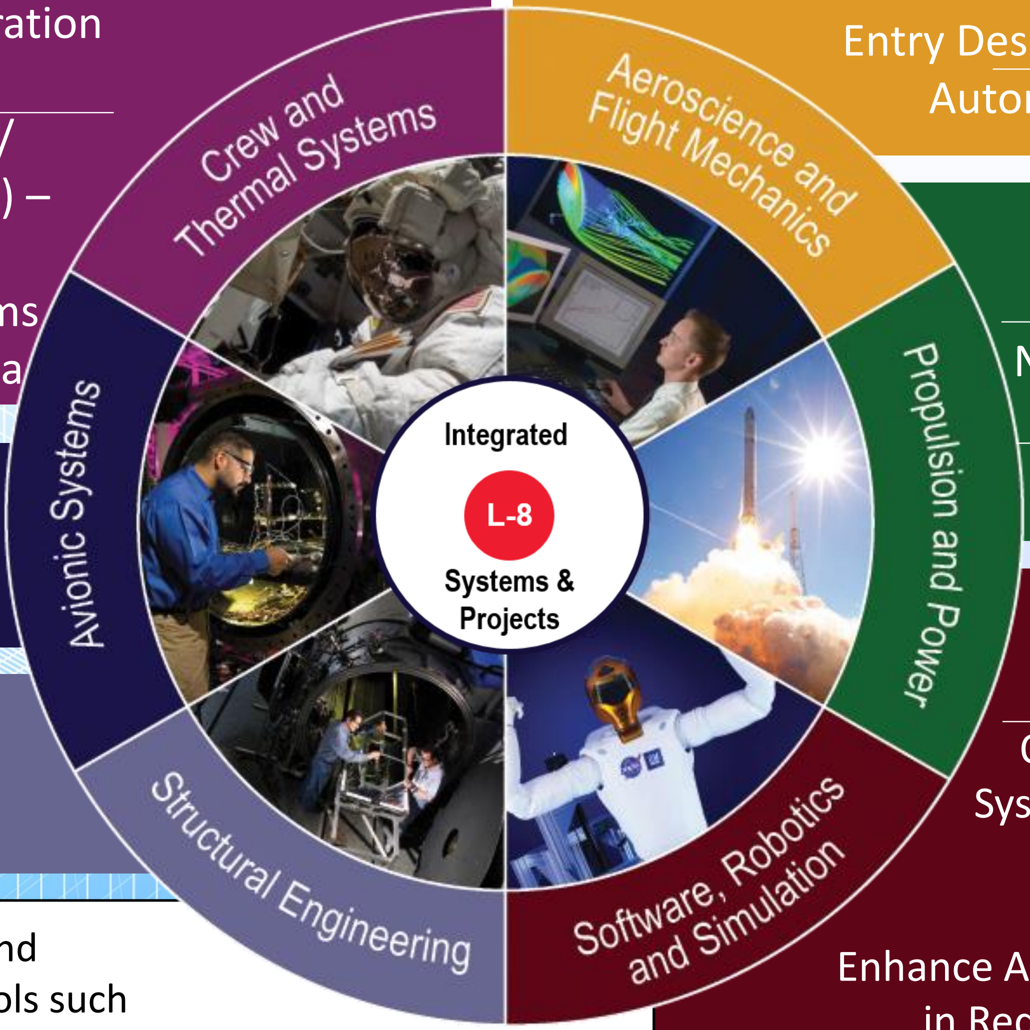
Space Environments Test Capability / James Webb Space Telescope (JWST) – Anchondo

Non-Venting Thermal Control Systems for Space Vehicles – Smith & Massina

RFID technology and sensor interrogators to develop low cost sensor suites - Wagner

Docking Systems and other Attachment/Release mechanisms and related technologies – Lewis

Modeling the integration of hardware and software systems of spacecraft using tools such as SysML - Carrejo




| AA-2 | iPAS | HESTIA | Morpheus

Entry Descent and Landing at Mars - Sostaric

Autonomous Mission Planning – Condon

In Situ Resource Utilization (ISRU) Capabilities – Sanders

NDE Methods for Ultimately Reliable Pyrotechnics – Scott & Hinkel

Safe Li-Ion batteries – Darcy & Scott

Spacecraft Autonomy – Badger

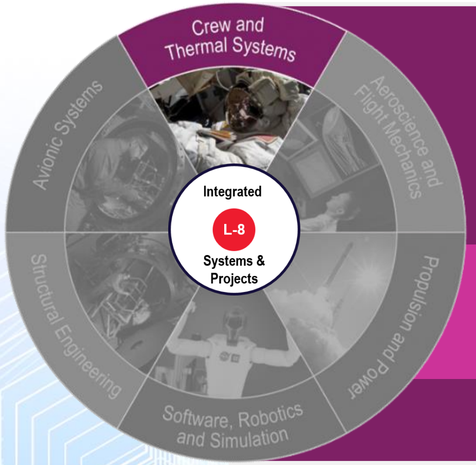
Advanced Vehicle Mobility – Junkin

Optimizing Virtual Reality and Tracking Systems for Zero-G Space Environments - Paddock

Using Human-Machine Interactions to Enhance Astronaut Performance and Adaptation in Reduced Gravity Environments - Burkhart

# Crew and Thermal Systems Technology Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Active Thermal Control
- Habitation Systems
- Life Support
- EVA

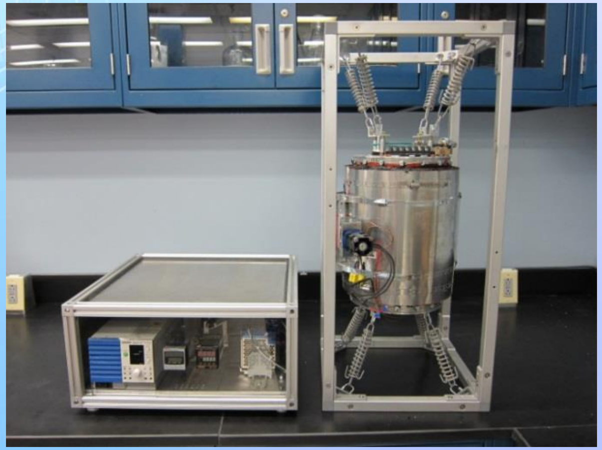
## The Problem

- We need to safely store tons of oxygen
  - likely in the form of water
- We need to safely convert most of the water to oxygen for breathing
  - low pressure O2 is fine, and it is safer to handle than high pressure O2
- We need to safely convert some of the low pressure oxygen to high pressure (3500 psi), high purity (>99.99%) oxygen for space suits

## Advanced Concepts for O2 Concentration and Storage

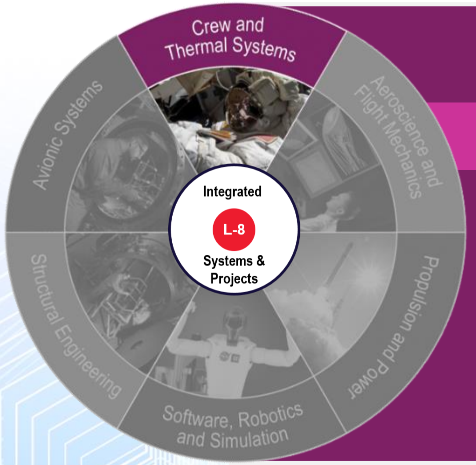
We are looking for collaborators to help develop technology for:

- Ambient pressure water electrolysis
- Oxygen extraction / separation from cabin air using solid oxide electrochemical oxygen concentrator
  - Possibly mechanical compression
  - Possibly solid state compression



# Crew and Thermal Systems Opportunity

*JSC Engineering: HSF Exploration Systems Development*




- Active Thermal Control
- Habitation Systems
- Life Support
- EVA

## The Problem

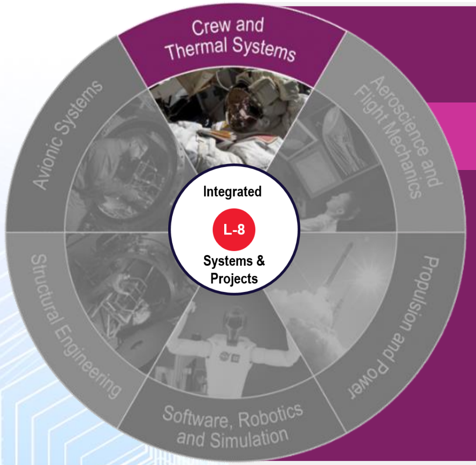
- Chamber A was designed for Apollo Lunar travel and Low Earth Orbit missions. (100 K environment)
- JWST needed a deep space environment (<20 K)
- NASA Science Directorate needs a facility for follow on missions (W-1st, Origins Surveyor)
- JSC needs a facility for testing beyond Low Earth and Mars surface environments.

## Space Environments Test Capability / James Webb Space Telescope

- For JWST we needed a deep space environment (Very Dark and Cold: <20 Kelvin)
- We collaborated with the cryogenics department at the DOE's Thomas Jefferson National Accelerator Facility
  - This collaboration was made possible by NASA's involvement in the Cryogenic Engineering Conference

# Crew and Thermal Systems Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Active Thermal Control
- Habitation Systems
- Life Support
- EVA

## Non-Venting Thermal Control Systems for Space Vehicles – <u>**Mars Surface Ascent/Descent**</u>

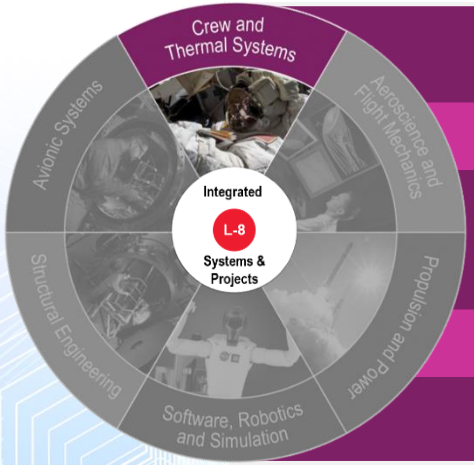
- Desired effort: identify candidate technologies capable of providing closed-loop thermal control through multiple ascents and descents of a single vehicle
- Develop a working prototype for feasibility evaluation at a NASA center
- Solution space is open

## The Problem

- Vehicle thermal control during ascent and descent phases has historically been achieved by venting a thermal control fluid of some kind.
- Eliminating consumable losses from the thermal control systems potentially reduces launch mass, resupply, and in situ resource utilization (ISRU) requirements for vehicles, while reducing the likelihood of forward planetary contamination.

# Crew and Thermal Systems Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Active Thermal Control
- Habitation Systems
- Life Support
- EVA

## The Problem

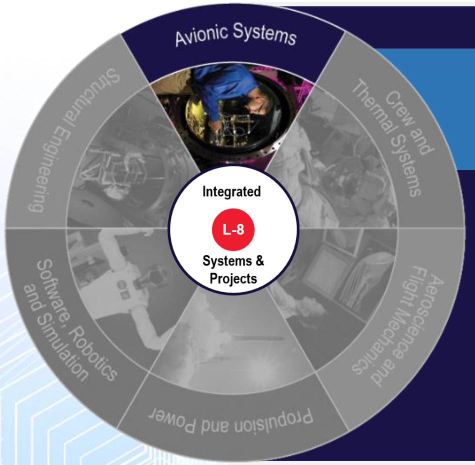
- Current space suit thermal control systems vent water at a rate of **~1 lb/hr**.
- Eliminating consumable losses from the space suit thermal control systems potentially reduces launch mass, resupply, and ISRU requirements.
- Current concepts pair venting systems with an absorber radiator to achieve near closed-loop operations.

## Non-Venting Thermal Control Systems for Space Vehicles – **Mars Surface Space Suits**

- Desired effort: identify and develop closed-loop space suit thermal control technologies
  - Eliminate all venting associated with EVA thermal control
- Some preliminary ideas:
  - Thermal energy storage or utilization devices
  - Life support robotics
  - Flexible radiators
- Many extensions to terrestrial PPE
- Develop a working prototype for feasibility evaluation at a NASA center
- Solution space is open

# Avionics Systems Opportunity

*JSC Engineering: HSF Exploration Systems Development*




- Wireless & Communication Systems
- Command & Data Handling
- Human System Interfaces
- Radiation & EEE Parts

## The Problem

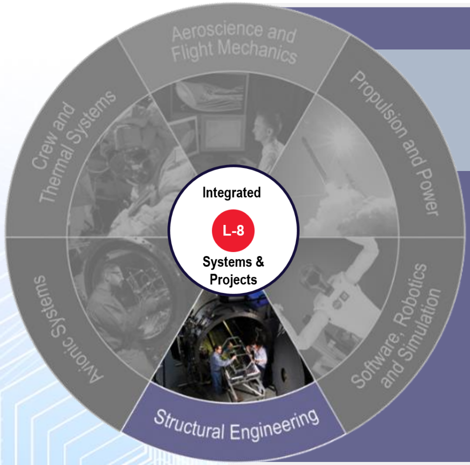
- wireless sensors can save significant vehicle mass, allow adding more instrumentation at later dates
- practical wireless sensing limited by short battery lifetimes
- current "active" protocols (WiFi, Bluetooth) not well suited to long-term vehicle sensing

## RFID technology and sensor interrogators to develop low cost sensor suites

- JSC/EV is developing a "zero-wire" sensing concept based on RFID
- RFID sensors are "passive"
  - no battery needed for communication
- path-to-flight hardware has been built/demonstrated (thermal sensors)
- partners sought for flight opportunities, further application development, demonstration (aerospace/otherwise)

# Structural Engineering Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Autonomous Rendezvous & Docking
- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Vehicle Environments

## The Problem

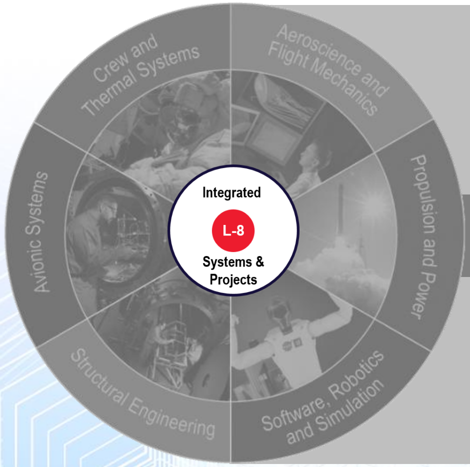
- JSC Engineering has responsibility for mechanical systems domain for advancing the current SOA to reduce mass, increase reliability, and increase performance for Human Space Exploration
- As humans and their systems leave low earth orbit (LEO) the reliability of mechanical systems has to increase as mass and volume decrease
- Flight proven systems are used at ISS today but were designed for LEO environments and a 90 min return to safety

## Docking Systems and other Attachment/Release mechanisms and related technologies

- Extend and enhance the current SOA capabilities in the areas of overall performance, reliability, mass, controls, feedback, & safety
  - Game-changing infusion of ideas, innovation, and/or technology
  - Survey/review of analogous or similar attachment release mechanisms/systems used in other remote or hazardous applications; especially in areas where increased autonomy/automation is occurring
- Relatively few groups or organizations exist which develop or use existing space based technology.
  - Continued growth in the area of “commercial” use of and access to space provides new market potential.
  - Continued push for standardization of systems and components will enable supply chain competition.
- Co-develop dual-use technologies
  - Reliability – academia/research based or remote environments (subsea, mining, oil & gas)
  - Performance – automated control (robotics, automated manufacturing)
  - Electronics/SW/Sensing – miniaturization, ruggedization, simplification
  - Environmental – radiation, extreme temps, vacuum, dust

# Integrated Systems and Projects Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Integrated Test & Verification
- System Modeling
- System Engineering & Integration

## The Problem

- Space systems are becoming increasingly complex
- Space systems are becoming increasingly intelligent
- Space systems are becoming increasingly autonomous
- Interactions among intelligent systems is not consistent and is incomplete
- Can NASA learn from other industry experience?

## Modeling the integration of hardware and software systems of spacecraft using SysML

<u>The Effort being proposed</u>

- We are implementing the use of a standard system modeling language (SysML) to describe space systems and their interactions

<u>The Idea we have</u>

- Each system can be represented at a high level and a detailed level. Any level of abstraction can be leveraged to demonstrate interfaces, activities, and states between systems

<u>Why is collaboration a good idea?</u>

- Complex and intelligent yet otherwise independent systems that require unattended intercommunication is common among many industries

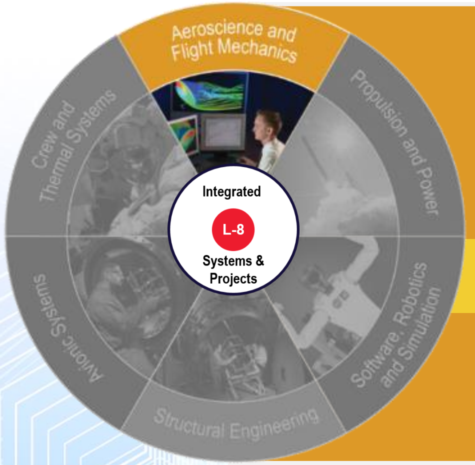
<u>The kind of Collaboration we envision</u>

- Modeling methodologies, product evaluations, success criteria

<u>The kind of partner we expect</u>

- Provider of systems analogous to space systems (smart home, manufacturing, self-driving cars, remote systems, Internet of Things)

# Aeroscience and Flight Mechanics




- Autonomous Rendezvous & Docking
- Entry, Descent, & Landing
- Deep Space GN&C

## The Problem

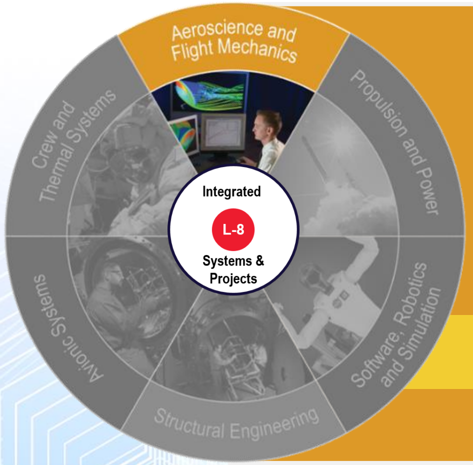
- *Desire to land increasingly large cargo on Mars, and humans in the 2030's*
- *State of the art Mars landed mass is ~1 metric ton (Curiosity rover)*
- *Need to land significantly larger mass payloads to support human missions*
- *Need to land on Mars safely, accurately, and repeatedly for human campaigns*

## Entry, Descent, and Landing at Mars

- *Develop a set of technologies to support human planetary landing:*
  - *Slowly*
    - *Entry decelerators*
  - *Accurately*
    - *Terrain Relative Navigation*
  - *Softly*
    - *Altimetry and velocimetry*
  - *Safely*
    - *Hazard Detection and Avoidance*

# Aeroscience and Flight Mechanics Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Autonomous Rendezvous & Docking
- Entry, Descent, & Landing
- Deep Space GN&C

## Autonomous Mission Planning

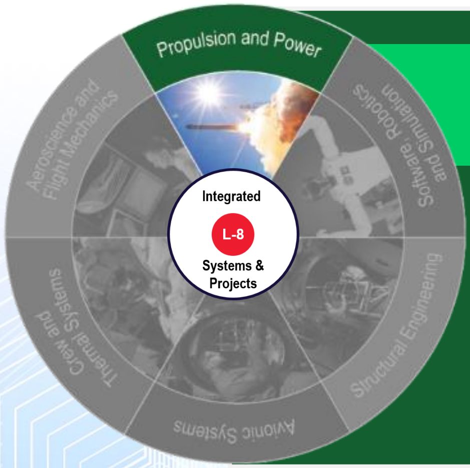
- Development of smart algorithms for a suite of Initial Guess Generators to support complex numerical optimization tools used onboard and inflight
- Algorithms include automatic tuners for the optimization tool's internal procedures such as numerical integration, array gradient calculations, and intelligent decision algorithms to guide and redirect complex optimization iteration sequences.
- This technology benefits both NASA (e.g., Orion) and commercial spacecraft that require autonomy
- Seeking interactive collaboration with the commercial sector and/or academia in the development of new technology for autonomous mission planning and trajectory design to support real time onboard operations in new flight regimes (e.g., Cislunar and Mars).

## The Problem

- As NASA prepares for long duration Mars missions, it becomes necessary to provide crew with onboard mission planning autonomy to increase crew safety and mission success
- This requires automatic and smart initial guess generators (IGE's) for onboard mission design and optimization tools
- SOA includes powerful mission design and optimization software (Copernicus) with IGE's for specific applications.

# Propulsion and Power Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Integrated Propulsion, Power, & ISRU
- Reliable Pyrotechnics
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

## The Problem

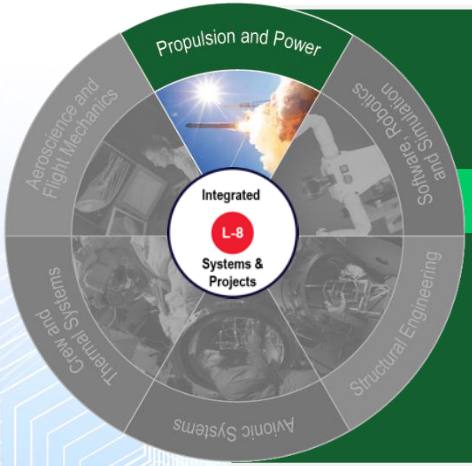
- **For every 1 kg landed on Mars, 7.5 to 11 kg has to be launched into orbit from Earth.**
- 23 mT of oxygen and 6.5 mT of methane propellants are needed for the Mars crewed ascent vehicle. This equates to the payload mass of 3 to 5 SLS launches
- Propulsion, power, and life support systems need to be designed from the start to use ISRU products
- Current ISRU technologies and systems are subscale engineering breadboards with limited space/Mars environmental testing

## In-Situ Resource Utilization Capabilities

- **NASA is developing technologies, systems, & operations to:**
  - **Find, extract, and process *in situ* resources**
  - **Store, transfer, and distribute products**
  - **Perform extraterrestrial civil engineering & construction**
- To maximize the benefits and minimize the mass and development costs, NASA is developing propulsion and power systems, which can be integrated with life support and thermal management systems, that use common ISRU-derived reactants and storage
- Developing and incorporating ISRU into human missions faces many of the same technology, infrastructure, environment, and deployment needs and challenges as the terrestrial mining, chemical processing, construction, and energy industries
- NASA hopes to partner by spinning-in and off technologies, operations, and best practices with industry through BAAs, CANs, SAAs, and SBIRs.

# Propulsion and Power Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Integrated Propulsion, Power, & ISRU
- Reliable Pyrotechnics
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

## The Problem

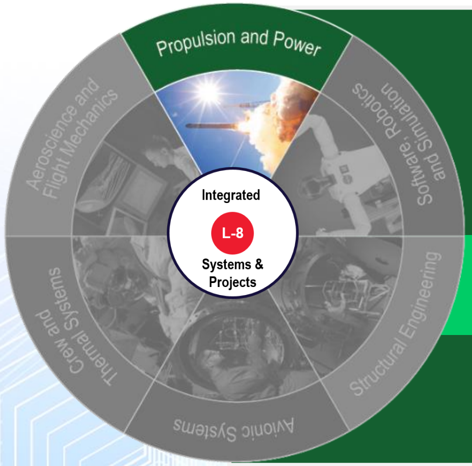
- Chemical contamination of pyrotechnic is not always detectable with current NDE methods.
- The effect if the contamination through destructive testing can take years to become evident.
- Current evaluation methods are mostly suitable for detecting solid metallic and nonmetallic FOD.

## NDE Methods for Ultimately Reliable Pyrotechnics

- NASA wants to explore the possibility of detecting chemical contamination in energetic devices through noninvasive means.
- Availability of this technology could provide nondestructive age surveillance of limited life devices on a routine basis, opposed to solely relying on destructive testing. This would increase the frequency of evaluation, advance the detection of defects, and expedite the replacement of suspect hardware.
- NASA would collaborate directly our partners in establishing inspection needs, detection sensitivity, pass/fail criteria for a variety of energetic material and components.

# Propulsion and Power Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Integrated Propulsion, Power, & ISRU
- Reliable Pyrotechnics
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

## The Problem

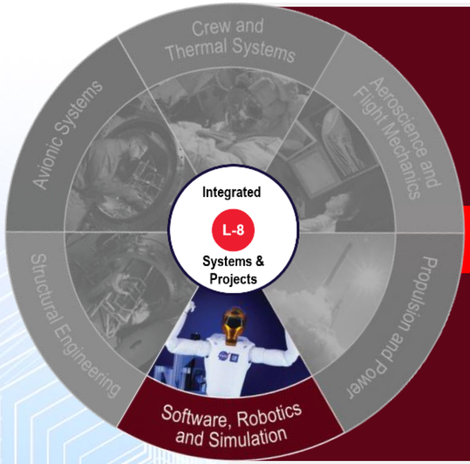
- Safe, high performing battery designs are need for human exploration to Mars
- Are 200 Wh/kg, 350 Wh/L battery designs possible that also are passively resistant to propagation of thermal runaway?
- Current SOTA safe battery is 120Wh/kg and 200 Wh/L
- We need increased production rate of reliable, consistent internal short circuit devices to enable battery safety verification testing with latest COTS cell designs achieving >275 Wh/kg, >730 Wh/L

## Safe Li-Ion Batteries

- The NREL/NASA On-demand Internal Short Circuit (ISC) Device is a critical method for triggering thermal runaway (TR) for battery verification testing with minimal alterations to the battery design
- These devices are currently made by hand using a laborious wax spin coating and reflow process
- We are seeking partners that can automate the manufacturing of these devices to make them more consistent and available to cell manufacturers and battery designers

# Software, Robotics, & Simulation Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

## The Problem

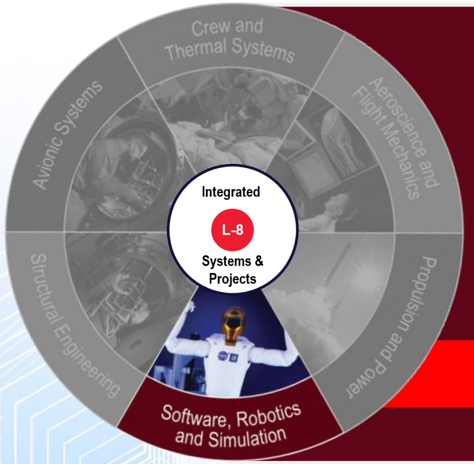
- Future exploration missions beyond low Earth orbit will require increasing independence from ground control
- Habitats and spacecraft may be left unattended (dormant) for significant periods
- NASA is interested in creating systems that can manage themselves and require less reliance on ground support to operate

## Spacecraft Autonomy

- Spacecraft need to operate independently from ground control
- JSC is creating an architecture to define autonomous capabilities
- JSC provides a rich example and test facilities to prove out various autonomous systems technologies and interfaces
- Interested in partners wishing to advance technology in autonomy, human-system interaction

# Software, Robotics, & Simulation Opportunity

*JSC Engineering: HSF Exploration Systems Development*




- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

## The Problem

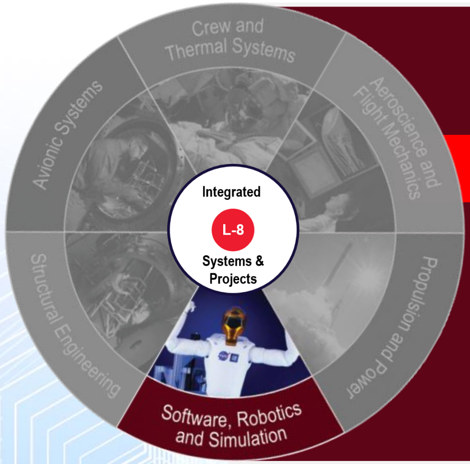
NASA is developing human rovers, also known as Space Exploration Vehicles (SEV), for The Moon and Mars. These rovers will be "Offroading RVs for Moon & Mars." There are many, many technical challenges that NASA faces in development of these vehicles. Some of the challenge areas include batteries, energy management, wheels, life support, radiation protection, and thermal control.

## Advanced Vehicle Mobility – Good for Mars, Great for Earth

- NASA has
  - Developed a Moon & Mars rover prototype currently in use for requirements development at the NASA Johnson Space Center
  - Developed a prototype small "car" with an industry partner with the same advanced mobility as the rovers that includes technologies needed for the Space Exploration Vehicles (SEV)
- NASA desires to
  - Share NASA's advanced mobility technology (steer by wire, driving algorithms, mechanical architecture, safety, etc.) with industry
  - Partner with industry to create the next vehicle using advanced mobility that allows NASA to advance the needed technologies for the SEVs AND produces a vehicle that is valuable to NASA's partner

# Software, Robotics, & Simulation Challenge

*JSC Engineering: HSF Exploration Systems Development*




- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

## The Problem

- **NASA would like to upgrade its current custom ISS VR training system with a more robust better performing commercial system**
- **VR integrated tracking system hardware and software need to work in a zero-g environment including rotational and translational tracking with 90Hz HMD graphics sync**
- **LEDs and laser dependent tracking systems can be problematic for space vehicles**
- **Current state of the art commercial HMDs with internal tracking systems are HTC Vive and Oculus Rift**

## Optimizing Virtual Reality and Tracking Systems for Zero-G Space Environments

- Optimization of commercial VR HMD and tracking systems to support VR training in Zero-0 space environments like ISS and Orion
- Idea is to optimize commercially available HMDs with internal or external tracking system executing on onboard laptops
- This would be a valuable and marketable solution for any micro-g VR training environment
- Looking for technical experts to solve VR system zero-g and real-time tracking (rotation & translation for HMD and avatar body parts) and any related graphics performance issues
- Looking for collaboration with commercial VR HMD (Rift or Vive) and tracking system experts

# Software, Robotics, & Simulation Challenge

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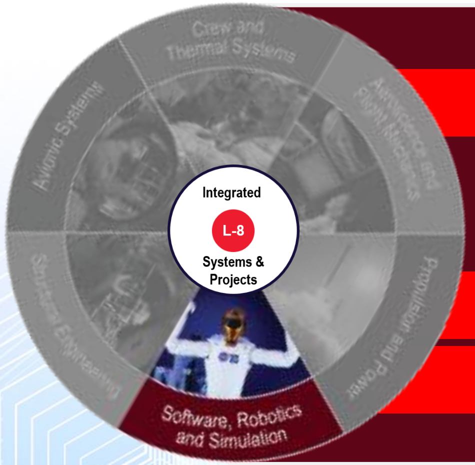



- Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics

## The Problem

***What is the current state of the art?***

- *Large, mechanically driven hardware with low data collection capability that requires multiple hardware elements to support crew health*

***What is the problem we are solving?***

- *New vehicles designed for deep space, and wide-spread commercial use applications, require a massively more compact unit, rooted in robotics and data collection, that provides a human-machine interface that creates individualized programing in any environment on Earth or in space*

***Why do we want to do this?***

- *A sensor enhanced, human-machine exercise unit provides crew, ground rehabilitation centers, and human performance groups with an unprecedented, individualized and intelligent system to customize for specific health and performance needs*

## Exercise System Applications of Robotics, Sensor, and Human-Machine Technologies to Enhance Individual User Performance and Adaptation

**What are we proposing?**

- *We seek to develop a compact, sensor rich, robotics/motor driven system that enhances both muscular and cardiovascular crew needs with additions of sensorimotor development that provides the crew with engineering and physiological feedback*

***What is our idea?***

- *Building a motor-based exercise unit that can be programmed with machine learning to individualize and tailor exercise protocols to users to promote increased health and performance outcomes in a small, reliable and robust unit*

***What is the benefit to a collaborator both in space and commercially?***

- *Currently there is no high-fidelity unit capable of meeting the needs of crew support for our efforts to reach Mars and beyond; the same unit required for this effort provides immense opportunity for success in rehabilitation clinics and athlete development arenas given the user-centric, individualized nature of the system*

***What kind of collaboration do we envision?***

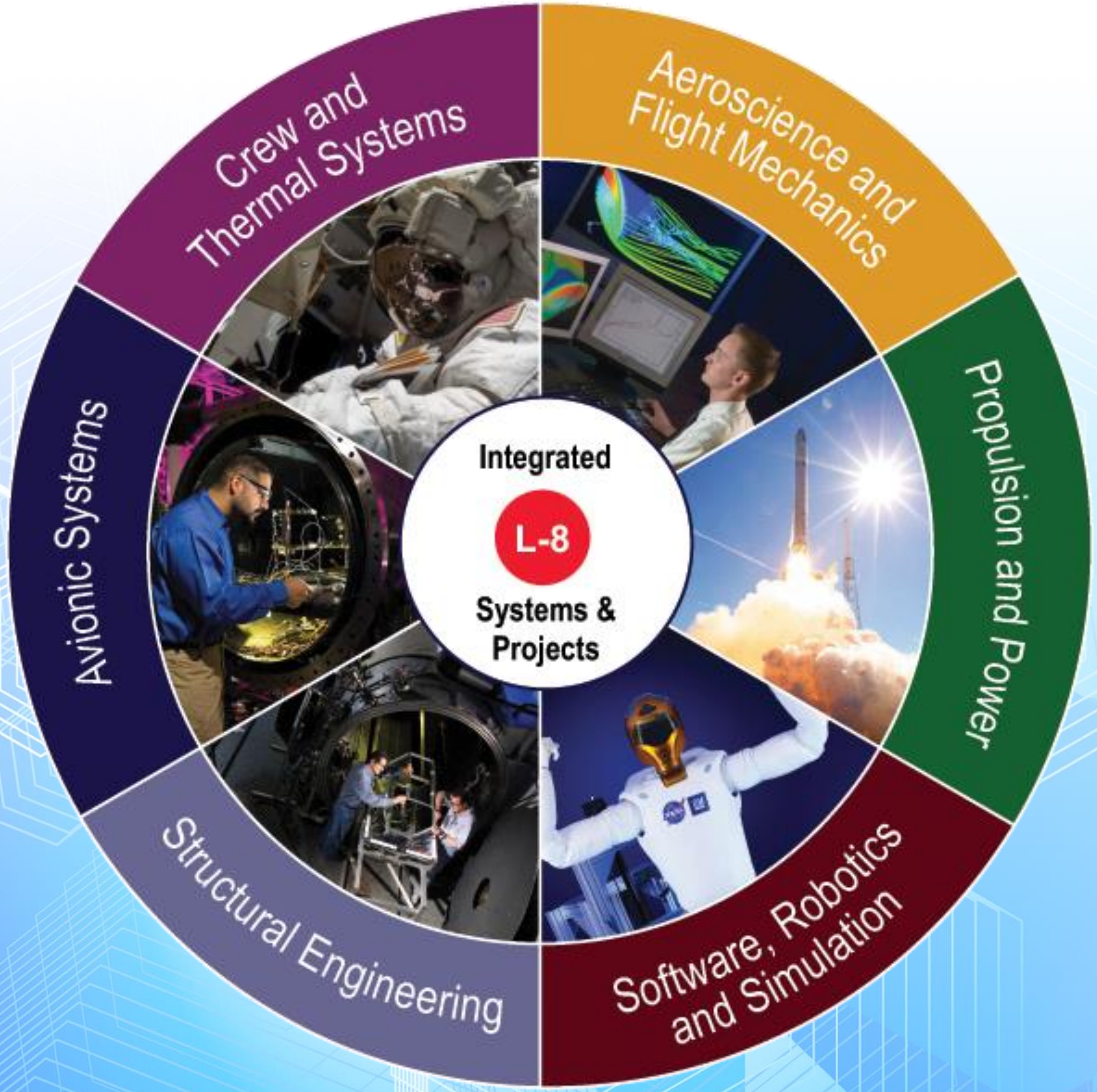
- *While our end-game is physiological improvement and sustainability, we see the symbiotic relationships of software developers, learning language applications, sensor experts, electronics/power/motor groups, and robotics, among many other disciplines, to support a human-centric methodology*

***What kind of partner do we want to grow with?***

- *We want a partner who understands that no matter the landscape, deep space or ground based, that the human comes before all else*

# Backup Information

*JSC Engineering: HSF Exploration Systems Development*



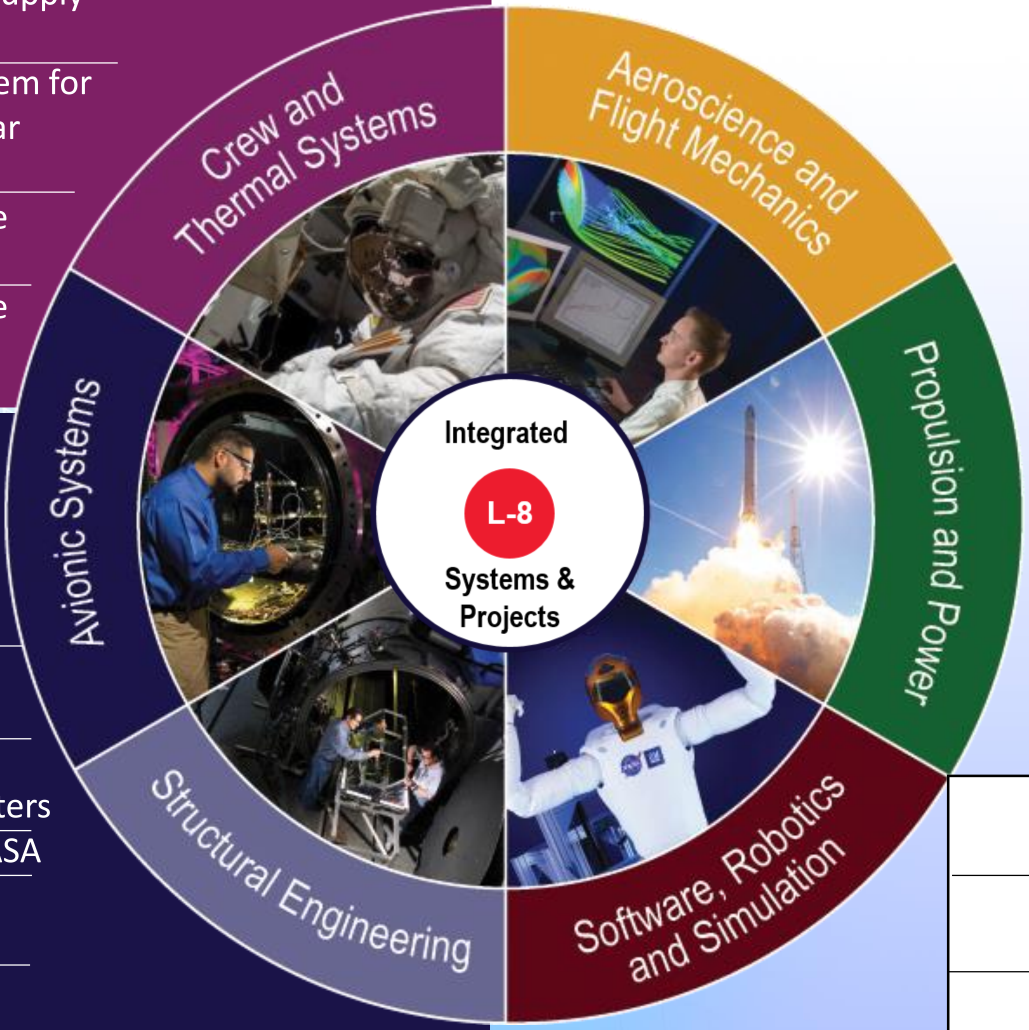

- Special Report(s)
- EA Challenges & Opportunities
- 2016 IRAD Investments
- 2017 IRAD Investments
- 2018 IRAD Investments

# TSGC Design Challenge Projects for Fall 2017 / Spring 2018 Semesters

*JSC Engineering: HSF Exploration Systems Development*

- A Low Power, Solid State Method of Oxygen Supply – UT Tyler (HEC) / KST-6
- Alternate Clothing Washing or Sanitizing System for Long Duration Space Missions – Lamar / Lamar Launderers (in progress)
- Micro-g Neutral Buoyancy Experiment: Zip Tie Cutter Challenge – UT Austin / Space Bevos
- Micro-g Neutral Buoyancy Experiment: Zip Tie Cutter Challenge – Lone Star College / Cero

- Prototype of a Space WiFi Mobile, Disruption-Tolerant, Ad-Hoc Mesh Network – SJC/ Mesh Things Up
- Intelligent Lighting Control System – UNT / Apollo's Legacy
- Intelligent Lighting Control System – TAMU / Aurora Aggies
- Use of Sonification for Spacecraft Situational Awareness Applications – TSU / The Soundmasters
- 3D Printed Antenna – TAMU / ISEN Team 10 NASA
- Spacecraft Lighting Network System (SLNS) – UNT / 2b||2b
- Olfactory Delivery System (ODS) Development – UT RGV / Tri-Force (in progress)



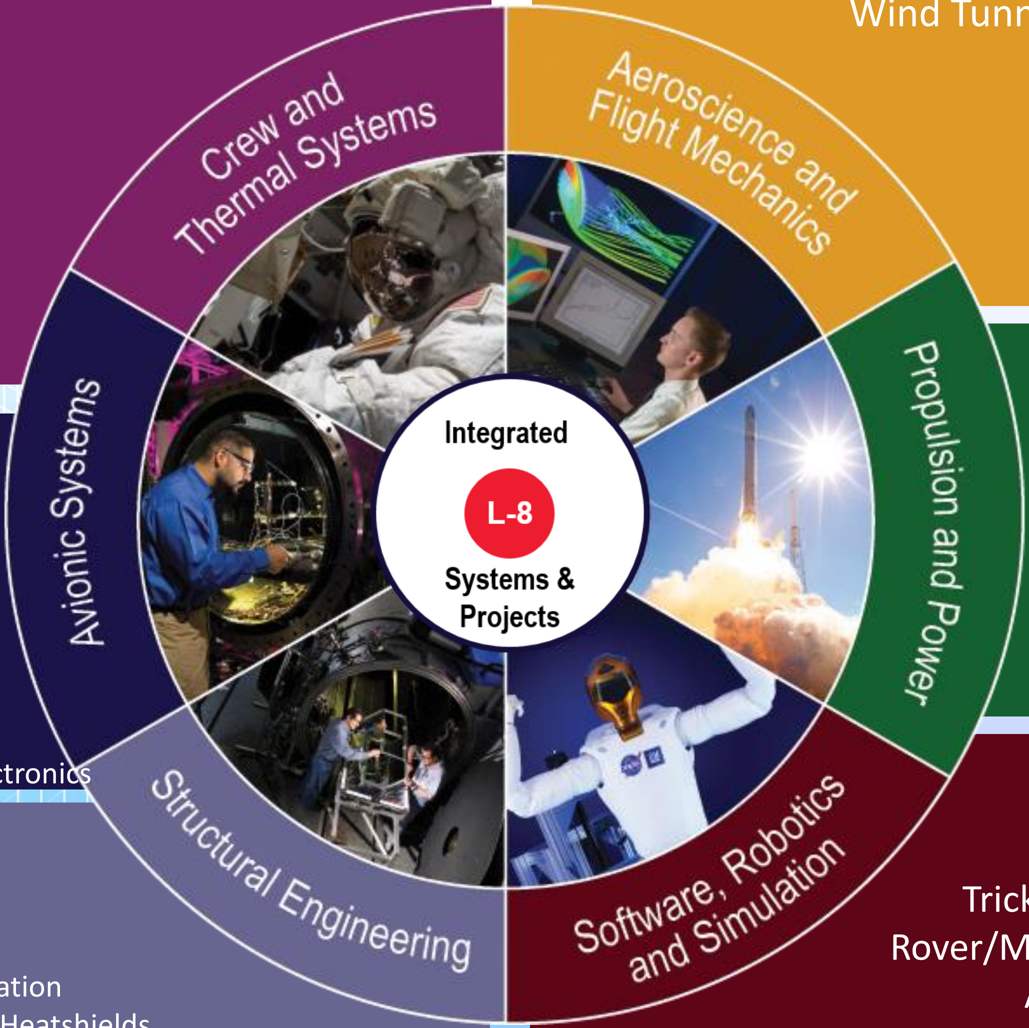

- Mars Sample Return System (MSRS) – TAMU Kingsville / Design Team 7
- Human-Tended Inflatable Lunar Outpost – Lamar / LU Space Engineers
- Mars Habitat & Initial Settlement Village – Lamar/ Orion's Crusaders

# Potential Collaborations with Academia

*JSC Engineering: HSF Exploration Systems Development*

CO2 Removal, CO2 Reduction
Trace Contaminant Control, Particulate Filtration
Reliable Brine Water Recovery (Low Volume)
Air Monitoring Techniques/Strategies
Variable Heat Rejection Technologies/Trades
Lightweight Bio-resistant CHX
Advanced Phase Change Materials
In-Situ Thermal Fluids Chemical Analysis
Solvent Generation for Reusable Wipes
Antimicrobial Omniphobic Surface Coatings

Wind Tunnel Tests for Supersonic Retro Propulsion & Mid-L/D Re-entry bodies,
Large Mass Mars Entry Trades,
Autonomous Landing
Hazard Avoidance Algorithms,
Optical Tracking and Navigation




Speech Recognition Evaluation
Natural Language Processing
Acoustic Echo Cancelation Algorithms (e.g., in a spacesuit)
Wearable Technologies
Power Scavenging Sensors
Mesh Network Implementations
RF over IP for testing
E-textile & 3D-printed antennas
Advanced manufacturing techniques for Sparing of Electronics

NDE Tools/Methods for Pyros,
LOx/LCH4 Propulsion Systems,
Lunar/Planetary In-Situ Resource Utilization,
“Propellant-less” Thrusters,
Thermionic Energy Conversion,
Non-Maxwellian Plasma Confinement Systems

Additive Manufactured Lattice Core Designs
Thin Ply Composites
Inflatable materials Creep characterization
Impact & Leak Detection for Inflatables
Acrylic & Ceramic Window Development & Characterization
Integrated Thermoelastic Design/Analysis Methods for Heatshields

Autonomous Grasping
Humanoid Walking
Integrated Dynamic Systems Simulation
Trick-based Software Simulation Enhancements
Rover/Mars Ascent Vehicle Cabin Design Integration
Augmented Reality Research & Applications
Autonomy Tools (Robotics Planning, Flight Director In a Box)