# American Institute of Aeronautics and Astronautics
# Houston Section
## Presents

# Annual Technical Symposium 2016

**NASA/JSC Gilruth Center**
**Houston, Texas**
**Friday, May 6, 2016**

# PROGRAM

**General Chair**

Justine Wiles

**Organizing Committee**

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Irene Chan
Michael Frostad
Anita Gale
BeBe Kelly-Serrato
Fred Ouellette
Alan Sisson
Laura Sarmiento
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Technical Committee Chairs

# CONTENTS

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| Time | Discovery | Longhorn | Lone Star | Coronado | Brazos |
|---|---|---|---|---|---|
| 7:30-8:00 | **Registration & Breakfast** *Alamo Ballroom* | | | | |
| 8:00-8:45 | **Welcome & Keynote Speaker -- Topic: The Orion Project** *Alamo Ballroom* | | | | |
| | **Discovery: Session A-1** | **Longhorn: Session A-2** | **Lone Star: Session A-3** | **Coronado: Session A-4** | **Brazos: Session A-5** |
| | *Theme-GN&C* | *Theme- Space Exploration* | *Theme- Astrodynamics* | *Human Exploration Spacecraft Testbed for Integration & Advancement* | **Career Development Hosted by EMERGE** |
| 8:50-9:15 | Ground-Based Navigation and Dispersion Analysis for Orion EM-1 | What Makes a Spacefaring Nation? | Minimum Delta-V Burn Planning for the ISS Using a Hybrid Optimization Tech, Level 1 | 8:50-9:15 HESTIA: Testbed for Exploration | |
| 9:20-9:45 | Orion Entry Monitor | Orion EFT-1 Post-Flight MMOD Inspection and Analysis | Wings for a Stellar "Jay" - Design Analysis Proceeding from Flight Paths | 9:20-9:35 Human in the Loop Ground Test - Value, History, and Future<br>9:35-9:55 HESTIA Support for Future NASA Deep-Space Missions | |
| 9:50-10:15 | Predictive Lateral Logic for Numerical Entry Guidance Algorithms | Reducing Edney Type-IV Shock-On-Lip Heating Via Leading Edge Shape Optimization | Hyperbolic Rendezvous at Mars: Risk Assessments and Mitigation Strategies | 9:55-10:15 HESTIA Phase 1 Test Results: Air Revitalization System | |
| 10:15-10:25 | **10 Minute Break** | | | | |
| | **Discovery: Session B-1** | **Longhorn: Session B-2** | **Lone Star: Session B-3** | **Coronado: Session B-4** | **Brazos: Session B-5** |
| | *Theme-GN&C + In-Space Imaging* | *Theme- Space Exploration* | *Theme- Astrodynamics + Systems Engineering* | *Human Exploration Spacecraft Testbed for Integration & Advancement* | **Career Development Hosted by EMERGE** |
| 10:25-10:50 | Lunar Entry Downmode Options for Orion | Basics of Atomic Hot Air Balloons for Planetary Exploration | Analytic Continuation Solution for the Perturbed Two-Body Problem | 10:25-10:50 Integrated Power and Propulsion | |
| 10:55-11:20 | Orbital Element Continuous Thrust Maneuvers Using Modified Chebyshev Picard Iteration | Flocks of Mass Produced Propulsion Units as an Interplanetary Mission Cost Saving Technology | | 10:55-11:20 CIF Propulsion | |
| 11:25-11:50 | On-orbit Clearance Assessment of External Coolant Line to HTV5 Port Thruster Nozzle | Feasibility of Transferring On-Orbit Components of the International Space Station for Solar System Exploration | Overview of NASA/SP-2015-3709, Human Systems Integration Practitioner's Guide | 11:25-11:50 Solid Oxide Fuel Cell | |
| 12:00-1:30 | **Mars Exploration Scenario Luncheon Panel** ***Alamo Ballroom*** | | | | |
| | **Discovery: Session C-1** | **Longhorn: Session C-2** | **Lone Star: Session C-3** | **Coronado: Session C-4** | |
| | | *Theme-Climate Change + EVA* | *Theme- Systems Engineering* | *Human Exploration Spacecraft Testbed for Integration & Advancement* | |
| 1:35-2:00 | Global AIS on Space Station (GLASS)/ Maritime Awarenes – Experiences and Lessons Learned from Developing and Manifesting an | Refocusing Air Climate and Energy Policy for Cooler Cleaner Air | NASA Quantitative Risk Assessment Applied to the Oil & Gas Industry | ISRU: Steam Methane Reformer | **Alamo Ballroom** |
| 2:05-2:30 | Architecture for Mitigating Short-Term Warning Cosmic Threats: READI Project | Hypoxia in Space? What the Past tells us for the Future... | Internet of Things at NASA | ISRU: Liquefaction | **Engineers as Educators Workshop (2pm-5pm)** |
| 2:35-3:00 | | Finding Solutions to NASA's SpaceSuit Water Intrustions during EVA | | ISRU: Cyrogenic EVA | |
| 3:05-3:30 | | | | ISRU: Commodities Pallet | |
| 3:35-4:00 | | | | Modeling and Simulation | |
| 4:00-5:00 | | | | | |

# SYMPOSIUM LOCATION

The American Institute of Aeronautics and Astronautics (AIAA), Houston Section, welcomes you to the 2016 Annual Technical Symposium at NASA/JSC Gilruth Center on May 6, 2016.

Enter Gilruth Center using JSC Public Access on Space Center Boulevard if you do not have a JSC badge. The morning and afternoon technical presentations are in the Lone Star, Coronado, Brazos and Longhorn Rooms on the second floor, and the Discovery Room on the first floor. Technical posters will be located in the Alamo Ballroom for the duration of the day. The morning keynote speech and the luncheon are on the first floor in the Alamo Ballroom.

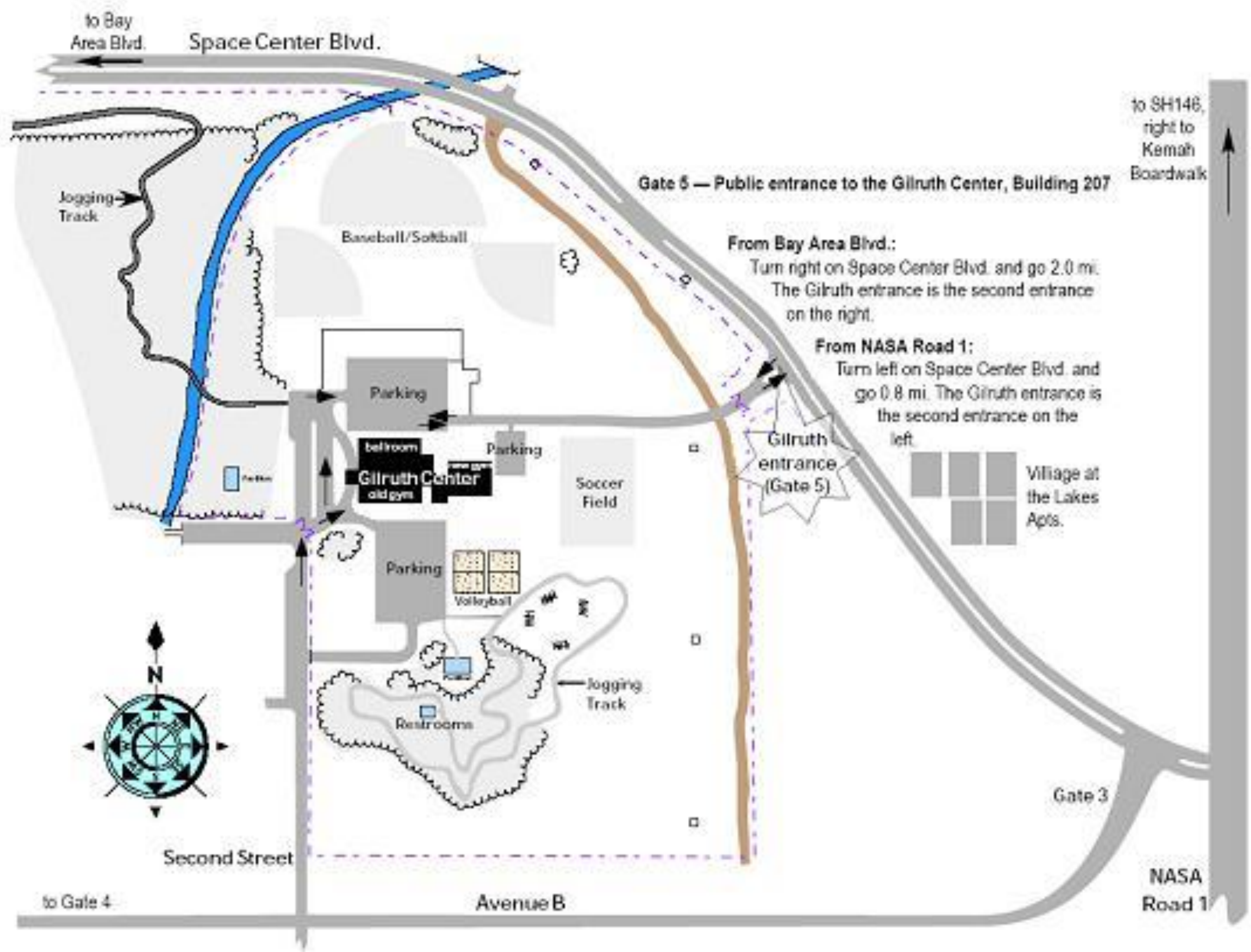


**Figure 1. JSC Gate 5 Public Entrance Map**

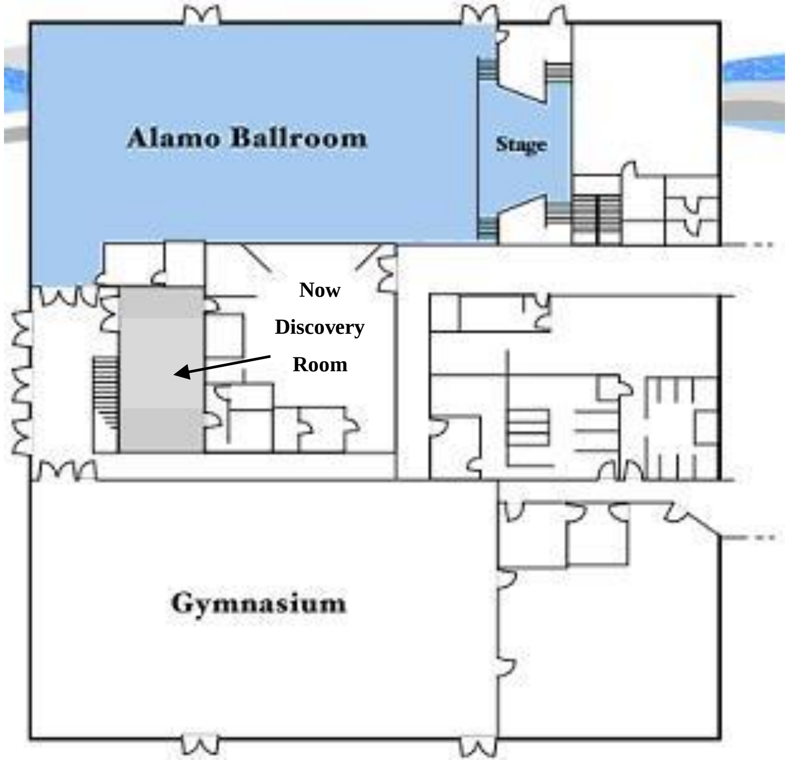


**Figure 2. Gilruth Center First Floor**

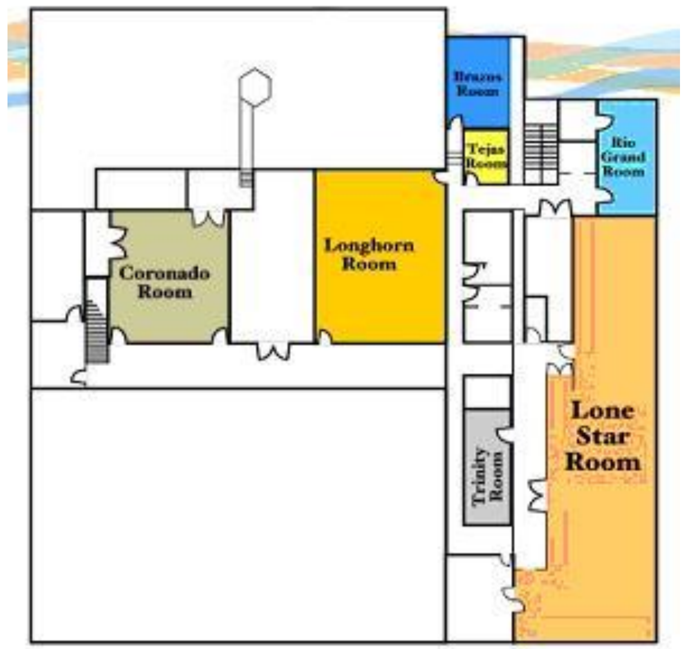


**Figure 3. Gilruth Center Second Floor**

# SYMPOSIUM INFORMATION

## REGISTRATION

Registration is $15 AIAA Student Members, $20 for AIAA Members, and $25 for non-members. All registrations include a light breakfast and lunch for all attendees and is open all day beginning at 7:45 AM. Advance registrations are required to obtain a lunch and are easy to do on the web at www.aiaahouston.org. The registration desk is located in the entry of the Alamo Ballroom. Registration is paid online. There is no additional fee for the buffet lunch – the cost is included in the registration fee.

## SPECIAL EVENTS

**Morning, 8:00-8:45 AM, Alamo Ballroom**

Welcome and Keynote:  The Orion Project

*Complimentary coffee, bottled water, assorted juices, and breakfast food provided*

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**Lunch, 12:00–1:30 PM, Alamo Ballroom**

Mars Exploration Scenario Panel Speakers

*Lunch buffet*
*Complimentary coffee, bottled water, Iced Tea*

# TECHNICAL PROGRAM

## Technical Sessions

**Session A-1** **Discovery Room**

## GN&C

**8:50 AM**

### A-1.1 GROUND-BASED NAVIGATION AND DISPERION ANALYSIS FOR THE ORION EXPLORATION MISSION 1

**Chris D'Souza**

This paper presents the navigation and dispersion analysis for the Orion Exploration Mission 1 (EM-1) Distant Retrograde Orbit (DRO) mission with ground-based navigation. This is a further analysis of the DRO trajectory along the lines of what was presented by D'Souza and Zanetti.

The accuracy of the flight-path angle at Entry Interface (EI) is driven by several factors including the navigation, targeting, and burn execution errors at the time of the last mid-course maneuver, and unaccounted trajectory perturbations between the last mid-course maneuver and EI.

Apollo missions tolerated a maximum flight path angle error at EI of 1 degree, with half of this error allocated to navigation. A similar criterion is employed in this study.

Perturbations are a major source of errors in the cislunar navigation performance of Orion. In a perfect world all the sources of perturbations would be modeled in the filter dynamics. However, computational limitations (and fundamental knowledge) preclude such extensive modeling. Therefore, the primary sources of perturbations are characterized. In particular there are three categories of unmodeled acceleration: propulsive sources, gravitational perturbations, and solar radiation pressure. Only propulsive errors are included in this analysis; the gravitational and solar radiation pressure are not included; they will be included in a future study. For EM-1, the gravitational and solar radiation pressure errors are several orders of magnitude below the thrusting sources. The propulsive sources considered are: attitude deadbands, attitude slews, CO2 venting, and sublimator venting.

Linear covariance techniques are used to perform the analysis for the Orion Cislunar missions. This comports well for the navigation system design since the cislunar navigation system on Orion will be an Extended Kalman Filter. Many of the same states and dynamics used in the linear covariance analysis will be used in the on-board cislunar navigation system. A preliminary design of the cislunar navigation system is presented. This is supported by linear covariance analyses which provides navigation performance, trajectory dispersion performance and Delta V usage.

**Presenter Biography:**
Chris D'Souza is Deputy Chief of the GNC Autonomous Flight Systems Branch and the Navigation Technical Discipline Lead at the Johnson Space Center. He has been at JSC since 2002; prior to that he worked at Draper (formerly The Charles Stark Draper Laboratory) for 9 years. He worked for the US Air Force at Eglin AFB specializing in GPS navigation for missiles. He also worked at the Jet Propulsion Laboratory on the Magellan and Galileo missions.

# GN&C

**9:20 AM**

## A-1.2 Orion Entry Monitor

**Kelly Smith**

NASA is scheduled to launch the Orion spacecraft atop the Space Launch System on Exploration Mission 1 in late 2018. When Orion returns from its lunar sortie, it will encounter Earth's atmosphere with speeds in excess of 11 kilometers per second, and Orion will attempt its first precision-guided skip entry. A suite of flight software algorithms collectively called the Entry Monitor has been developed in order to enhance crew situational awareness and enable high levels of onboard autonomy. The Entry Monitor determines the vehicle capability footprint in real-time, provides manual piloting cues, evaluates landing target feasibility, predicts the ballistic instantaneous impact point, and provides intelligent recommendations for alternative landing sites if the primary landing site is not achievable. The primary engineering challenges of the Entry Monitor is in the algorithmic implementation in making a highly reliable, efficient set of algorithms suitable for onboard applications.

**Presenter Biography:**
Kelly Smith is an aerospace engineer at NASA's Johnson Space Center and supports the Orion GN&C team and Mars 2020 Cruise, Entry, Descent, and Landing team. Smith graduated with a bachelor's degree from Iowa State University in 2010.

# GN&C

**9:50 AM**

## A-1.3 Predictive Lateral Logic for Numerical Entry Guidance Algorithms

**Kelly Smith**

Recent entry guidance algorithm development123 has tended to focus on numerical integration of trajectories onboard in order to evaluate candidate bank profiles. Such methods enjoy benefits such as flexibility to varying mission profiles and improved robustness to large dispersions. A common element across many of these modern entry guidance algorithms is a reliance upon the concept of Apollo heritage lateral error (or azimuth error) deadbands in which the number of bank reversals to be performed is non-deterministic. This paper presents a closed-loop bank reversal method that operates with a fixed number of bank reversals defined prior to flight. However, this number of bank reversals can be modified at any point, including in flight, based on contingencies such as fuel leaks where propellant usage must be minimized.

**Presenter Biographies:**
Kelly Smith is an aerospace engineer at NASA's Johnson Space Center and supports the Orion GN&C team and Mars 2020 Cruise, Entry, Descent, and Landing team. Smith graduated with a bachelor's degree from Iowa State University in 2010.

# Space Exploration

**8:50 AM**

## A-2.1 What Makes a Spacefaring Nation?

**Stacy Clifford**

In August 2014, former NASA Administrator Mike Griffin told the crowd at the Mars Society Convention, "we are not a spacefaring nation." This essay explores the meaning of that statement. We briefly review the history of great seafaring nations such as the Greeks, Venetians, and Portuguese, and how their cultures and accomplishments help us define the term "spacefaring nation." Reasons that America does not meet that definition are examined, and we identify the root causes that need to be corrected in order to qualify as a spacefaring nation.

**Presenter Biographies:**
Stacy Clifford is a native Houstonian and a member of the Mars Society of Houston, now Mars Astronautics Space Technologies (MAST), since 1999. He as a degree in geology from the University of Texas at Austin, where he wrote a paper on Martian lava tube habitats, and has been a self-employed webmaster since 2006. In his spare time he is also an artist and a Renaissance martial arts instructor with a passion for history.

# Space Exploration

**9:20 AM**

## A-2.2 Orion EFT-1 post-flight MMOD inspection and analysis

**Joshua Miller**

Orbital debris in the millimeter size range can pose a hazard to current and planned spacecraft due to the high relative impact speeds in Earth orbit. Fortunately, orbital debris has a relatively short life at lower altitudes due to atmospheric effects; however, at higher altitudes orbital debris can survive much longer and has resulted in a band of high flux around 700 to 1,500 km above the surface of the Earth. While large orbital debris objects are tracked via ground based observation, little information can be gathered about small particles except by returned surfaces, which until the Orion Exploration Flight Test number one (EFT-1), has only been possible for lower altitudes (400 to 500 km). The EFT-1 crew module backshell, which used a porous, ceramic tile system with surface coatings, has been inspected post-flight for potential micrometeoroid and orbital debris (MMOD) damage. This paper describes the pre- and post-flight activities of inspection, identification and analysis of six candidate MMOD impact craters from the EFT-1 mission.

**Presenter Biography:**
Conferred doctorate from the University of Rochester in Rochester, New York in Mechanical Engineering specializing in High Energy Density Physics. Currently, a Principal Research Scientist for the University of Texas at El Paso tasked in support of NASA Johnson Space Center (JSC) under the JSC Engineering and Technical Support (JETS) contract in the role of evaluating and developing impact performance models for spacecraft survivability.

# Space Exploration

**9:50 AM**

## A-2.3 Reducing Edney Type-IV Shock-On-Lip Heating Via Leading Edge Shape Optimization

**Patrick E. Rodi**

High speed vehicles incorporating ramjet/scramjet propulsion systems usually employ a “shock-on-lip” condition to maximize engine mass capture. In this scenario, the forebody-induced shock wave impinges onto the leading edge of the engine cowl. Such an impingement can cause shock-shock interactions that produce extremely high convective heating rates to the cowl. Due to such interactions, the cowl leading edge region often experiences the greatest convective heating rates found on the vehicle. Earlier research has produced an optimized leading edge generation process applicable for high speed vehicles such as waveriders; wherein Bezier Curves are employed to represent the candidate leading edge cross sectional geometries which are then optimized using a number of cost functions including: minimum peak heating, minimum total heating, minimum drag, and minimum pressure gradient.
In the current work, Bezier Curve leading edges have been used in a new optimization process with the goal of reducing the heating to a cowl leading edge by modifying the local shock-shock interaction via geometry modifications. Since these shock-shock interactions are fundamentally an inviscid phenomenon, the Euler equations are used to evaluate configurations as input to a Particle Swarm Optimization process. Such optimized cowl leading edge geometries have been generated at Mach 4.6 and have applications to high speed vehicles using an air-breathing propulsion system. Results from a single-shock wave based optimization process show up to an 8% reduction in peak pressure on the leading edge.

**Presenter Biography:**
Dr. Patrick E. Rodi is a Lockheed Martin Fellow specializing in aerodynamics, aerothermodynamics, optimization, and grid generation. Patrick received his Ph.D. from The Center for Hypersonic Training and Research at The University of Texas at Austin. Dr. Rodi joined Lockheed Martin Skunk Works in 1996, where he worked on a number of hypersonic programs including the X-33 and FALCON. Patrick became the LM-Houston Aerosciences Lead for the Orion Multi-Purpose Crew Vehicle in 2007. Dr. Rodi is an AIAA Associate Fellow and has authored over three dozen technical papers.

# Astrodynamics

## 8:50 AM

## A-3.1 Minimum Delta-V Burn Planning for the International Space Stations Using a Hybrid

**Aaron Brown**

The International Space Station's (ISS) trajectory is coordinated and executed by the Trajectory Operations and Planning (TOPO) group at NASA's Johnson Space Center. TOPO group personnel routinely generate look-ahead trajectories for the ISS that incorporate translation burns needed to maintain its orbit over the next three to twelve months. The burns are modeled as in-plane and along the local horizontal axis, and must meet operational trajectory constraints imposed by both NASA and the Russian Space Agency. In generating these trajectories, TOPO personnel must determine the number of burns to model, each burn's Time of Ignition (TIG), and magnitude (i.e. Delta-V) that meet these constraints. The current process for targeting these burns is manually intensive, and does not take advantage of more modern techniques that can reduce the workload needed to find either feasible burn solutions that simply meet the constraints, or optimal burn solutions that minimize the total Delta-V while simultaneously meeting the constraints. A two-level, hybrid optimization technique is proposed to find both feasible and globally optimal burn solutions for ISS trajectory planning. For optimal solutions, the technique breaks the optimization problem into two distinct sub-problems, one for choosing the optimal number of burns and each burn's optimal TIG, and the other for computing the minimum total Delta-V burn solution that satisfies the trajectory constraints. Each of the two aforementioned levels uses a different optimization algorithm to solve one of the sub-problems, giving rise to a hybrid technique. Level 2, or the outer level, uses a genetic algorithm to select the number of burns and each burn's TIG. Level 1, or the inner level, uses the burn TIGs from Level 2 in a sequential quadratic programming (SQP) algorithm to a minimum total Delta-V burn solution subject to the trajectory constraints. The total Delta-V from Level 1 is then used as a fitness function by the genetic algorithm in Level 2 to select the number of burns and their TIGs for the next generation. In this manner, the two levels solve their respective sub-problems iteratively until a burn solution is found that globally minimizes the Delta-V across the entire trajectory. Feasible solutions can also be found by simply using the SQP algorithm in Level 1 with a zero cost function.

This paper discusses the formulation of the Level 1 sub-problem and the development of a prototype software tool to solve it. The Level 2 sub-problem will be discussed in a future work. A key technical feature of the Level 1 formulation is the use of trigger functions and state transition matrices to compute the objective and constraint gradients used by the SQP algorithm. Following the Level 1 formulation and solution, several look-ahead trajectory examples for the ISS are explored. In each case, the burn targeting results using the current manual process are compared against a feasible solution found using Level 1 in the proposed technique. Level 1 is then used to find a minimum Delta-V solution given the fixed number of burns and burn TIGs. The optimal solution is compared with the previously found feasible solution to determine the Delta-V (and therefore propellant) savings.

The proposed technique seeks to both improve the current process for targeting ISS burns, and to add the capability to optimize ISS burns in a novel fashion. The optimal solutions found using this technique can potentially save hundreds of kilograms of propellant over the course of the ISS mission compared to feasible solutions alone. While the software tool being developed to implement this technique is specific to ISS, the concept is extensible to other long-duration, central-body orbiting missions that must perform orbit maintenance burns to meet operational trajectory constraints.

**Presenter Biography:**

Aaron began work at the NASA Johnson Space Center (JSC) in the Fall of 2000. He started in the International Space Station (ISS) Trajectory Operations group, became certified as an ISS Trajectory Analyst (TA), and then as a full Trajectory Operations Officer (TOPO) in 2004. Aaron supported the STS-115 mission in the Fall of 2006. At the end of 2006, he moved out of the TOPO group and began conducting trajectory analysis work for several beyond-LEO programs, including NASA's Constellation and Orion Programs. In 2014, Aaron transitioned from the Flight Operations Directorate to the Engineering Directorate, and began supporting development of Orion's onboard Guidance, Navigation, and Control (GNC) system. Aaron's recent efforts have been in developing software tools to analyze and support the ISS mission, Orion's Exploration Flight Test 1 (EFT-1) mission, and Orion's Earth-Moon 1 & 2 (EM-1 & EM-2) missions.

# Astrodynamics

**9:20 AM**

## A-3.2 Wings for a Stellar "Jay" – Design Analysis Proceeding from Flight Paths

**Wes Kelly**

The Stellar J design is based on our organization's concept for a reusable first stage vehicle operable from conventional airfields, providing small satellite launch capability. The concept is scalable to larger applications and missions of greater complexity but the version for small satellites resembles a Gulfstream III in weight and the dimensions, carrying expendable upper stages of several tons mass for small satellite payloads of several hundred pounds to low earth orbit.

For a decade we have simulated the flight phases, detailing the reference design and examining trade issues. The first stage ascent includes a conventional winged aircraft take off and ascent to subsonic cruise and stratospheric altitude, similar to a commercial liner, and then ignition of a rocket engine for climb to burn-out conditions for expendable stage separation, targeted as high as 200,000 feet and Mach 7. Thereafter the stage returns to land down range or back at its original field via a glide return to low altitude at high angle of attack with transition to conventional cruise to its landing target. In the course of these investigations we varied upper stage payload mass, burn times and shut-down velocities, angles of attack on re-entry and bank maneuvers to vector toward the launch site or airfields down range.

All of these procedures result in variations of thermal and aero loads which have consequences for structures and the design of a suitable wing for both subsonic and hypersonic flight. We are currently examining leading edge heating loads for the baseline design to determine both airfoil and l material selections for leading edges and internal structures. Cross sections of these elements are under consideration as well.

These latest studies are more complex than previous ones since they require modeling heat diffusion relations and efforts to establish structural loads, tasks usually done with finite element tools. Yet much undertaken is in the name of preliminary or intermediate design trades with consequent examination of more concepts than usually addressed by finite element procedures. By necessity we have managed to discover means to subordinate this problem to methods of multi-discipline study and in searching for "common denominators" for this particular vehicle, we found parameters to track usually not associated with ballistic rocket flight.

While this is a project that is related to commercial space, it is primarily related to design integration on a new vehicle. Elements of this interdisciplinary problem can be considered astrodynamics which we have discussed in the past (e.g. at ATS 2014), but we will concentrate on flight elements considerably lower than orbital velocity. It is certainly in interest of commercial space. Perhaps we are not so much charting new territory in aerodynamics (wing, airfoils, structures and heating) as re-examining it in the context of a hybrid vehicle part aircraft and part spacecraft, employing wings, rockets, turbofan engines and relying on lift. The pay-off will be material selections (aluminum, titanium, inconel, composites …) in weights and cross sections suited to the reusable delivery vehicle mission.

**Presenter Biography:**
After serving with the USAF from 1966 to 1970, Wes Kelly attended the University of Michigan in Ann Arbor where he obtained a BS in Aerospace Engineering in 1973, and a subsequent MS in Aeronautics and Astronautics from the University of Washington (Seattle) in 1978. He has worked in flight mechanics, trajectory analysis and design projects in varying phases in Seattle, Houston, New Orleans and Denver. Many of these projects were related to the Shuttle, the space station, launch vehicles, payloads and upper stages. In 2004 he founded Triton Systems, LLC a small engineering firm which has done engineering work at the NASA Johnson Space Center and is a partner with ORBITEC supporting the NASA Glenn Research Center propulsion technology program (RTAPS 1 and 2). Mr. Kelly and his Triton associates have been working for over a decade to develop a family of reusable launch vehicles. Their efforts have obtained several letters of intent from small satellite manufacturers and the interest of the Ellington Space Port.

# Astrodynamics

## 9:50 AM

### A-3.3 Hyperbolic Rendezvous at Mars: Risk Assessments and Mitigation Strategies

**Richard Jedrey**

Given the current interest in the use of flyby trajectories for human Mars exploration, a key requirement is the capability to execute hyperbolic rendezvous. Hyperbolic rendezvous is used to transport crew from a Mars centered orbit, to a transiting Earth bound habitat that does a flyby. Representative cases are taken from future potential missions of this type, and a thorough sensitivity analysis of the hyperbolic rendezvous phase is performed. This includes early engine cutoff, missed burn times, and burn misalignment. A finite burn engine model is applied that assumes the hyperbolic rendezvous phase is done with at least two burns.

**Presenter Biography:**
Richard Jedrey is an aerospace engineer with the Flight Mechanics and Trajectory Design Branch at Johnson Space Center. His work focuses on orbital mechanics and trajectory design for Orion and advanced missions. Some of the projects Richard has worked on include trajectory design and analysis for Exploration Missions -1 and -2, Proving Ground mission design, and Mars mission designs, such as NASA's Design Reference Architecture 5.0, The Inspiration Mars Foundation, and Mars Lite. Richard supports the Orion On-Orbit Performance Team, which has received multiple Space Flight Awareness Awards.

Richard received his Bachelor's and Master's Degrees in Aerospace Engineering at The Ohio State University. He started working for NASA as a cooperative education student in 2007, and began working in the Flight Mechanics and Trajectory Design Branch in 2011.

Richard will be presenting on risk assessments and mitigation strategies for the utilization of hyperbolic rendezvous at Mars. Hyperbolic rendezvous may allow for a vast reduction in propellant loading, thereby decreasing an overall Mars mission mass and cost. Richard has authored and co-authored these other publications:

Jedrey, R., "Development of a Discretized Model for the Restricted Three-Body Problem," The Ohio State University, 2011, M.S. Thesis.

Jedrey, R., Joyce, E., Snyder, M., "Preliminary Mars Ascent Rendezvous Study," AIAA SPACE 2010 Conference and Exposition, August-September 2010, AIAA 2010-8755.

Gutkowski, J., Dawn, T., Jedrey, R., "Evolution of Orion Mission Design for Exploration Mission 1 and 2," AAS GN&C Conference, February 2016, AAS 16-111.

Whitley, R., Jedrey, R., Landau, D., "An Alternative Humans to Mars Approach: Reducing Mission Mass with Multiple Mars Flyby Trajectories and Minimum Capability Investments," AIAA Space Conference 2015, August 2015.

**Session B-1** **Discovery Room**

# GN&C

**10:25 AM**

## B-1.1 Lunar Entry Downmode Options for Orion

**Kelly Smith**

For Exploration Missions 1 and 2, the Orion capsules will be entering the Earth's atmosphere with speeds in excess of 11 km/s. In the event of a degraded Guidance, Navigation, and Control system, attempting the nominal guided entry may be inadvisable due to the potential for failures that result in a loss of vehicle (or crew, when crew are aboard). In such a case, a method of assuring Earth capture, water landing, and observance of trajectory constraints (heating, loads) is desired. Such a method should also be robust to large state uncertainty and variations in entry interface states. This document will explore four approaches evaluated and their performance in ensuring a safe return of the Orion capsule in the event of onboard system degradation.

**Presenter Biography:**
Kelly Smith is an aerospace engineer at NASA's Johnson Space Center and supports the Orion GN&C team and Mars 2020 Cruise, Entry, Descent, and Landing team. Smith graduated with a bachelor's degree from Iowa State University in 2010.

**Session B-1** **Discovery Room**

# GN&C

**10:55 AM**

## B-1.2 Orbital Element Continuous Thrust Maneuvers Using Modified Chebyshev Picard Iteration

**Julie L. Read**

Previous studies using a novel propagation technique called Modified Chebyshev Picard Iteration (MCPI) have simulated hybrid thrust transfers to rendezvous with space debris in Earth orbit. These studies include a two-impluse manuever at the terminal boundaries, which is augmented with continuous low-thrust that is sustained for the duration of the flight. These studies combine the capabilities of the MCPI method to solve both Initial Value Problems (IVP) and Boundary Value Problems (BVP). Extremal field maps may be then generated using either serial or parallel computation to determine the preferred thrust method as well as to distinguish globally optimal from infeasible and sub-optimal orbit maneuver regions. Since MCPI is inherently suited to parallel computation, additional studies have shown that implementing the algorithms on a compute cluster decreases the computation time.

The present work solves for optimal continuous thrust (using an indirect method) and implements a set of Modified Equinoctial Orbital Elements (MEE) in place of cartesian coordinates, which has shown to converge over a much larger number of orbits using MCPI; for the IVP the convergence domain is increased from around 3 orbits to 17 orbits, for the fully spherical harmonic (40×40) gravity case. This is expected to lead to a larger convergence domain for the BVP; over 1 orbit is expected compared with about 1/3 orbit as shown previously for the cartesian case. The power of this algorithm lies in the fusion of the variables chosen with the propagation method, leading to a large domain of convergence. The solution obtained using the MEE approach may be verified against previous results using cartesian coordinates.

**Presenter Biography:**
Julie Read is a PhD student in Aerospace Engineering at Texas A&M University advised by Dr. John Junkins. Her research focuses on a novel propagation technique called Modified Chebyshev Picard Iteration (MCPI) with applications in orbital mechanics.

Julie earned her B.S. in Electrical & Computer Engineering from the University of Wyoming in 2007 and a M.S. in Aerospace Engineering from Texas A&M in 2010. She worked at a private aerospace company, Odyssey Space Research, for 2.5 years before returning to Texas A&M for her PhD. She is currently seeking a job in the JSC community.

**Session B-1** **Discovery Room**

# In-Space Imaging

**11:25 AM**

## B-1.3 On-orbit Clearance Assessment of External Coolant Line to HTV5 Port Thruster Nozzle

**Donn Liddle**

In 2010, during Shuttle Mission STS-130, a set of MLI wrapped coolant transfer lines were installed externally from the US Lab to Node-3. A CAD model of the line's "approximate" location was generated from points at which the crew reported securing the ammonia line, but its accuracy was never validated.

In December 2015, HTV5 was scheduled to be berthed at the Node-1 Nadir CBM adjacent to the coolant line. A clearance assessment using the approximate CAD model revealed at 4" negative clearance with the HTV's port thruster nozzle. Since it was immediately recognized that the CAD model was approximate at best, the Image Science and Analysis Group (IS&AG) was requested to model the true location of the MLI wrapped coolant lines to determine if the HTV thruster nozzle would truly impact the lines.

This presentation will discuss how over a single weekend IS&AG was able to use existing STS-130 fly-around imagery to generate a stereo model of the "as-installed" coolant line and the Node-1 nadir CBM to verify a minimum 5" positive clearance with the HTV5 thruster nozzle. The analysis was repeated using updated SSRMS camera imagery acquired in the summer of 2015 which confirmed 7 to 10 inches of positive clearance. The results of this analysis relieved the ISS program of a need to conduct an EVA to relocate the coolant lines. IS&AG has since generated a new CAD model of the location of the "as-installed" coolant lines to update the ISS master CAD model.

**Presenter Biography:**
Donn Liddle holds a BS in Survey Engineering, an MS in Civil Engineering from California State University at Fresno, with postgraduate work at The Ohio State University. He specialized in the field of industrial measurement and close range photogrammetry. He is the Lead Photogrammetrist in the Image Science and Analysis Group (IS&AG) at NASA's Johnson Space Center where he is responsible for planning and performing quantitative image analyses in support of manned space flight activities.

# Space Exploration

## 10:25 AM

### B-2.1 Basics of Atomic Hot Air Balloons for Planetary Exploration

**Chris Y. Taylor**

Hot-air balloons, also known as Montgolfier balloons, powered by heat from radioisotope decay are a potentially useful tool for exploring planetary atmospheres and augmenting the capabilities of other exploration technologies. This paper describes the physical equations and identifies the key engineering parameters that drive radioisotope-powered balloon performance. Figures of merit for destination atmospheres and balloon technologies are presented and reviewed for various likely destinations and balloon designs.

**Presenter Biography:**
Christopher Y. Taylor is an AIAA Senior Member, Member of AIAA Nuclear and Future Flight Propulsion TC, former Houston Section Project Chair, Former Chairperson of NFFP TC, Former NFFP TC Congressional Visits Day rep., two time former Houston ATS presenter.

PUBLICATIONS:
Taylor, C.Y., “A 'Back of the Envelope' Look at Space Launch Vehicle Costs,” presented at the 2004 AIAA Houston Advanced Technology Symposium, NASA/JSC, 2004.
Taylor, C.Y., “In Defense of External Tanks,” presented at the 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, AIAA-2006-4784, Sacramento, CA, 2006.
Hansen, J. and Taylor, C.Y., “Curie-Montgolfiere Planetary Explorers,” presented at the 2007 Space Technology and Applications International Forum, Albuquerque, NM, 2007.
Taylor, C.Y., “Mass Produced Flock of Propulsion Units for Interplanetary and Interstellar Mission Cost Reduction,” presented at the 19th Adv. Space Propulsion Workshop, Huntsville, AL, 2012

EDUCATION:
Bachelor of Engineering in Mechanical Engineering, Vanderbilt University, May 1993
AIAA Professional Studies Course: Aircraft Conceptual Design, June 1994
AIAA Professional Studies Course: Liquid Rocket Propulsion, July 2000
AIAA Professional Studies Course: Elements of Spacecraft Design, April 2001
AIAA Professional Studies Course: Economics of Space Transportation, Oct. 2002
AIAA Professional Studies Course: Elements of Design of Experiments, Dec., 2005

An independent consultant to energy organizations since 2004. Work includes designing a hydraulic walking system that moves fully erected oilrigs at roughly the same speed as the Apollo/Shuttle crawler for orders of magnitude less money, size, and hassle.

# Space Exploration

## 10:55 AM

## B-2.2 Flocks of Mass Produced Propulsion Units as an Interplanetary Mission Cost Saving Technology

**Chris Y. Taylor**

An independent, objective engineering assessment of the Anthropogenic Global Warming controversy has been completed by an all-volunteer research team, comprised primarily of retired NASA scientists and engineers who are veterans of the Apollo Program. This paper will report on the results and conclusions of this three-year study assessing the extent to which continued, unrestricted burning of fossil fuels can warm the planet. Our conclusion, based on 165 years of physical data since CO2 levels began to rise in our atmosphere analyzed with simple models derived from Conservation of Energy, is that the planet will run out of economically recoverable fossil fuels before any harmful global warming can occur. This paper will help translate the jargon, methods and sources of uncertainty hobbling climate science, into terminology and well-developed radiation heat transfer analysis methods typically used by aerospace engineers. We concluded climate scientists claim large uncertainty in future global warming caused by burning fossil fuels, only because they give credence to the results of very complex, but un-validated, climate simulation models computing hypothesized climate changes that might occur hundreds to thousands of years into the future.

**Presenter Biography:**
Christopher Y. Taylor is an AIAA Senior Member, Member of AIAA Nuclear and Future Flight Propulsion TC, former Houston Section Project Chair, Former Chairperson of NFFP TC, Former NFFP TC Congressional Visits Day rep., and two time former Houston ATS presenter.

PUBLICATIONS:
Taylor, C.Y., “A 'Back of the Envelope' Look at Space Launch Vehicle Costs,” presented at the 2004 AIAA Houston Advanced Technology Symposium, NASA/JSC, 2004.
Taylor, C.Y., “In Defense of External Tanks,” presented at the 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, AIAA-2006-4784, Sacramento, CA, 2006.
Hansen, J. and Taylor, C.Y., “Curie-Montgolfiere Planetary Explorers,” presented at the 2007 Space Technology and Applications International Forum, Albuquerque, NM, 2007.
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AIAA Professional Studies Course: Elements of Spacecraft Design, April 2001
AIAA Professional Studies Course: Economics of Space Transportation, Oct. 2002
AIAA Professional Studies Course: Elements of Design of Experiments, Dec., 2005

An independent consultant to energy organizations since 2004. Work includes designing a hydraulic walking system that moves fully erected oilrigs at roughly the same speed as the Apollo/Shuttle crawler for orders of magnitude less money, size, and hassle.

# Space Exploration

### 11:25 AM

## B-2.3 Feasibility of Transferring On-Orbit Components of the International Space Station for Solar System Exploration

**Shen Ge and Yvonne Vigue-Rodi**

NASA's International Space Station is the most complex and sophisticated structure ever built by human beings. The nearly 1,000,000 pound orbiting laboratory has been flying in earth orbit since its first components were launched in November of 1998. Adelante Sciences' analysis team has been studying the feasibility of re-purposing and transferring individual or groups of Space Station components into new research locations across the solar system. Once the ISS completes its primary mission, NASA should consider the benefits and opportunity to gradually and carefully dis-assemble and slowly transfer usable components into new locations outside of Earth orbit, for further manned-space exploration opportunities. Future exploration mission types and candidate research solar system destinations will be presented, as well as the types of propulsion technology that would be needed to accomplish the successful transfer of existing ISS components into their new research destinations, which could include Lunar and Mars orbits, and Asteroid Rendezvous Exploration missions.

**Presenter Biography:**
Shen Ge has a Masters degree in Aerospace Engineering from Texas A&M and dual bachelors degrees in Aerospace Engineering and Physics from Georgia Tech. After earning his Masters Degree, he led the formation of a nonprofit space education organization in Europe and organized its founding conference. Concurrently, he worked under Art Dula at private company Excalibur Almaz focused on spacecrafts and reentry vehicles. In the fall of 2012, he secured a large grant and founded a research company ECAPS LLC with three Texas A&M colleagues and his graduate school mentor Dr. David Hyland to work on asteroid deflection using the method of space power coating he conceived. In 2014, he worked at Triton Launch Systems under Wes Kelly, a small satellite launch vehicle company developing a reusable horizontal take-off and landing vehicle. In 2015, he was part of a four-person founding team working on a B2B solar energy platform for utilities and also explored the potential of drones for rooftop site surveys. Lastly, he has been developing a STEM workshop for students to learn engineering through an asteroid detection competition where they build a mock satellite and work in teams.

Yvonne Vigue-Rodi received BS and MS degrees in Aerospace Engineering from the University of Texas at Austin. She spent 17 years at NASA JPL in Pasadena, California, developing advanced GPS technology for geophysics and oceanography from space. In 2007, Yvonne joined the ISS GN&C Team at Jacobs Technology in Houston, Texas, conducting ISS Assembly GN&C verification analysis for NASA JSC. In 2011, Yvonne founded Adelante Sciences Corporation in Houston, Texas, to develop advanced technology for the aerospace, defense and transportation industries.

# Astrodynamics

**10:25 AM**

## B-3.1 Analytic Continuation Solution for the Perturbed Two-Body Problem

**Kevin Hernandez**

Recent developments have been introduced to the analytic continuation power series based solution for the two body problem. These have enabled the integration of orbits avoiding the numerical stability issues traditionally encountered using this approach. The introduction of scalar variables, inspired by Battin's Lagrange invariants, is used to obtain recursive formulas for the higher order analytic derivatives while avoiding division operations; Horner's summation scheme is also implemented; and a variable time step allows for improved efficiency. These, together, reduce the numerical stability issues encountered in the past and provide two tuning parameters.

Results for LEO, HEO and GEO including zonal perturbation terms J2-J6 preserve 14-16 digits accuracy in conservation of energy after one orbit, and similar accuracy in position during 1-orbit round trip closure is obtained. Additionally, a simple atmospheric drag model called cannonball drag has been introduced together with the J2-J6 zonal terms and implemented on LEO also achieving 14-16 digits of accuracy in round trip closure accuracy.

Our implementation of analytic continuation method is described followed by a study of the conservation of energy, round trip closure accuracy and computational cost as a function of the tunning parameters. A discussion of the results and future work will be discussed at the end.

**Presenter Biography:**
Kevin Hernandez is a Ph.D. student in Aerospace Engineering at Texas A&M University advised by Drs. John Junkins and James Turner. His research focuses on a novel propagation technique called Analytic Continuation with applications in orbital mechanics.

Kevin earned his B.Sc. and Ph.D. in Physics from the Simón Bolívar University in Venezuela in 2006 and 2010, respectively. He came to the U.S. right after completing his Ph.D. in Physics to start his Ph.D. at Texas A&M.

# Systems Engineering

**11:25 AM**

## B-3.3 Overview of NASA/SP-2015-3709, Human Systems Integration (HSI) Practitioner's Guide

**Mychal Miller**

The NASA/SP-2015-3709, Human Systems Integration (HSI) Practitioner's Guide, also known as the "HSIPG," provides a tool for implementing HSI activities within the NASA systems engineering framework. The HSIPG is written to aid the HSI practitioner engaged in a program or project (P/P), and serves as a knowledge base to allow the practitioner to step into an HSI lead or team member role for NASA missions. Additionally, the HSIPG is written to address the role of HSI in the P/P management and systems engineering communities and aid their understanding of the value added by incorporating good HSI practices into their programs and projects. HSI has been successfully adopted (and adapted) by several federal agencies-most notably the U.S. Department of Defense (DoD) and the Nuclear Regulatory Commission (NRC)-as a Methodology for reducing system life cycle costs (LCCs). Cost savings manifest themselves due to reductions in required numbers of personnel, the practice of human-centered design, decreased reliance on specialized skills for operations, shortened training time, efficient logistics and maintenance, and fewer safety-related risks and mishaps due to unintended human/system interactions. The instructions and processes identified are best used as a starting point for implementing human-centered system concepts and designs across programs and projects of varying types, including manned and unmanned, human spaceflight, aviation, robotics, and environmental science missions. The HSIPG provides an "HSI layer" to the NASA Systems Engineering Engine (SEE), detailed in NASA Procedural Requirement (NPR) 7123.1B, NASA Systems Engineering Processes and Requirements, and further explained in NASA/SP-2007-6105, Systems Engineering Handbook.

**Presenter Biography:**
David has been working in the JSC community for 32 years supporting MPAD (Mission Planning and Analysis Division), MOD (Mission Operations Directorate), and Engineering in the areas of trajectory and GN&C. He is currently NASA Lead of the Orion GN&C Orbit MODE Team (OMT).

# Communication and Tracking

**1:35 PM**

## C-1.1 GLobal AIS on Space Station (GLASS) / Maritime Awareness – Experiences and Lessons Learned from Developing and Manifesting an Applied Research Project to the ISS

**Martin Tschirschwitz**

In September 2014 the Center for the Advancement of Science in Space (CASIS) awarded a grant to JAMSS America, Inc. (JAI) to conduct applied research on the International Space Station (ISS). The primary objective of the research is to demonstrate the benefits of using the ISS National Laboratory assets as an advantageously located, reliable and maintainable research platform to successfully acquire and rebroadcast Automatic Identification System (AIS) signals received from commercial ships for subsequent processing and distribution. The project, "Global AIS on Space Station" (GLASS), seeks to demonstrate that the reception and use of specialized proprietary processing of Channels A and B ship AIS data and future Satellite AIS channels by GLASS has substantial commercial, security and societal value. Potential benefits include increasing safety and efficiency of local and regional port operations, forecasting economic impacts of international maritime shipping, reducing the negative environmental impacts and high fuel costs of commercial shipping, enhancing national security and overall Maritime Domain Awareness in ISS-visible coastal, brown water (intra-coastal) and blue water regions.

The ISS-based GLASS equipment, to be located in the Columbus module, consists of a redundant Software Defined Radio system employing multiple, simultaneously active, virtual receivers, redundant data processors and routers. The active virtual receivers process VHF signals from an antenna externally mounted on an ISS structure. The antenna provides a wide view of the Earth's surface and is able to gather AIS signals from vessels underway and in harbor.

The received AIS signals are processed within the GLASS computer and delivered via a router for onward transmission to Earth through the ISS Ku Forward payload data downlink as shown in Figure 1. Once received at the ground segment, the GLASS receiver data is then processed for practical and analytical applications using GLASS-proprietary software. The downlinked data also contains payload health & status information.

In addition to receiving and passing data to the ground, commands can also be issued to the GLASS receiver via the same path back to the ISS. The command capability allows control of the GLASS receiver without routine ISS crew intervention. This flexibility enables the land-based technical team to maintain the system as well as upload new software and reconfigure the receiver as desired throughout its mission lifetime.

The GLASS equipment will be ready for flight to the ISS in Spring 2016 and is manifested for launch on the SpaceX-9 mission in Summer 2016. Following commissioning of the equipment on the ISS, the GLASS project will enter a twelve-month operational evaluation period during which time the raw AIS data packets and the information derived from processing of the AIS signals will be furnished to selected interested parties for their evaluation and use.

Since receiving the grant award in September 2014 the GLASS Team has transitioned from a proposal team to a functioning project team. This included finalizing the Grant Agreement with CASIS, as well as agreements with each collaborator and all contractors. The process of manifesting and preparing a payload to be launched on a visiting vehicle and installed on the ISS can be daunting. The GLASS Team continues to work closely with NASA and its contractors, with assistance from CASIS's operations and contracts personnel as needed, to navigate through the manifesting and safety processes as efficiently as possible while adhering to ISS program requirements.

In this paper we will briefly describe the GLASS project, its launch vehicle and ISS integration status of the GLASS payload (NASA OpNom "Maritime Awareness"). We will then focus on our related experiences and lessons learned to date while addressing the following questions:

- What are the expected advances to be realized through GLASS applications over existing ground-based and space-based maritime monitoring systems?

- What technological solutions does the use of the ISS enable for the GLASS project that are not available to other space-based AIS systems?
- What are the lessons learned for our future projects to be flown to the ISS and for other entities considering projects on the ISS? We will address the technical, administrative and contractual challenges we have encountered to initiate the project, develop the ground and flight systems, prepare for the 12-month operational evaluation period and look ahead to transitioning the project to a long-term operational enterprise.

Lastly, the paper will offer insights based on our experience as to what NASA and CASIS could do to improve the technical and operational experience and to further facilitate the commercial potential of initiatives such as GLASS who desire to utilize the U.S. National Laboratory's assets.

**Presenter Biography:**
2014 – Present: Project Manager/ISS Payload Developer; GLobal AIS on Space Station (GLASS) Project Lead for all project planning, payload hardware and software development, testing, ISS requirements verification, real-time operations and evaluation of scientific/commercial project objectives for the ISS payload "Maritime Awareness", which is a CASIS sponsored 1 year on-orbit research project onboard the ISS U.S. National Laboratory, slated for launch on SpaceX-9 in Summer 2016.

2012 – Present: Sr. Engineer ISS Program Support Group, JAMSS America, Inc., Houston, TX; Representing JAXA's interests at ISS Management and Operations meetings. Providing real-time on-console support at NASA-JSC ISS Management Center (IMC) for JEM & HTV operations. Maintaining JAXA/NASA/CASIS liaison to promote a JEM Utilization Information Center in the US as well as act as a CASIS Implementation Partner.

1999 – 2012: Sr. Shuttle/ISS Cargo Integration & Operations Engineer, Astrium North America, Inc. (now Airbus DS Space Systems), Houston, TX. Served as flight operations lead during 12 Shuttle missions, managing the Integrated Cargo Carrier (ICC) flight support team, supporting simulations and real-time on-console flight operations at JSC MCC. Provided astronaut training for more than 50 EVA crewmembers at the Neutral Buoyancy Laboratory (NBL) and during crew hands-on reviews with flight hardware. Served as the lead engineering interface between NASA Shuttle/ISS Program, payload customer organizations and Germany-based engineering teams for flight hardware design, development and analyses. Served as senior engineer responsible for structural, thermal, EVA and robotics interface requirements verification. Supported flight hardware integration and turnover processes at the Astrium hardware integration facility at Cape Canaveral, FL.

1995 – 1999: Structural Test Manager, EADS Astrium Space Transportation (no Airbus Defence & Space), Bremen, Germany. Managed structural qualification and acceptance test programs of sub-systems and components for the European launcher Ariane 4 and 5, ESA satellites and Columbus. Oversaw test planning, preparation, operations, data acquisition/processing and reporting.

**Session C-1** **Discovery Room**

# International Space Activities

**2:05 PM**

## C-1.2 Architecture for Mitigating Short-Term Warning Cosmic Threats: READI Project

**Jackelynne Silva-Martinez**

Earth is being constantly bombarded by a large variety of celestial bodies and has been since its formation 4.5 billion years ago. Among those bodies, mainly asteroids and comets, have the potential to create large scale destruction upon impact. The only extinction-level impact recorded to date was 65 million years ago, during the era of dinosaurs. The probability of another extinction-level, or even city-killer, impact is negligible, yet it is highly imperative for us to be prepared for such a devastating impact in the near future. The majority of scientists, engineers, and policymakers have focused on long-term strategies and warning periods for Earth orbit crossing Near-Earth Objects (NEOs), and have suggested methods and policies to tackle such problems. However, less attention has been paid to short warning period NEO threats. Such NEOs test current technological and international cooperation capabilities in protecting ourselves, and can create unpredictable devastation ranging from local to global scale. The most recent example is the Chelyabinsk incident in Russia. This event has provided a wakeup call for space agencies and governments around the world towards establishing a Planetary Defense Program. The Roadmap for EArth Defense Initiative (READI) is a project by a team of international, intercultural, and interdisciplinary participants of the International Space University's Space Studies Program 2015 hosted by Ohio University, Athens, OH proposing a roadmap for space agencies, governments, and the general public to tackle NEOs with a short warning before impact. Taking READI as a baseline, this paper presents a technical description of methodologies proposed for detection and impact mitigation of a medium-sized comet (up to 800m across) with a short-warning period of two years on a collision course with Earth. The hypothetical comet is on a highly-inclined orbit having a high probability for detection after its perihelion. For detection, we propose a space-based infrared detection system consisting of two satellites located at the Earth-Moon Lagrange points L1 and L2 coupled with space observatories, like the James Webb telescope and the Centennial telescope. These telescopes are supported by ground-based telescopes, like the Arecibo and Green Bank telescope, in the search for NEOs. Upon detection, the comet is tracked constantly using space- and ground-based telescopes. The deflection system is two-pronged, firstly involving the use of a high energy Directed Energy Laser Terminals (DELT) placed at Sun-Earth Lagrange points L4 and L5 so as to initiate and increase the ablation rate of the comet and deviate it from its collision trajectory, and secondly by the Hypervelocity Comet Intercept Vehicle (HCIV), a space-borne system combining a kinetic impactor with a thermonuclear device. The policy and international collaboration aspects to implement these methods are also outlined in the paper. The techniques mentioned could also be applied to mitigate medium-to-large sized asteroids (up to 2km across).

**Presenter Biographies**:
Jackelynne Silva-Martinez was born in Cusco, Peru. She worked for Lockheed Martin Space Systems as a Mechanical Engineer and Systems Integration & Test Engineer for commercial and government satellite programs. She then worked at NASA Jet Propulsion Laboratory performing verification and validation ground tests for the Mars Science Laboratory mission. Currently, Jackelynne works at NASA Johnson Space Center in the Flight Operations Directorate. Jackelynne graduated from Rutgers University as a Mechanical and Aerospace Engineer, obtained a Master's Degree in Aeronautical Science Human Factors from Embry-Riddle Aeronautical University, and is currently completing a second Master's Degree in Aerospace Systems Engineering at Georgia Institute of Technology. Jackelynne is an alumna of the 2015 Space Studies Program from the International Space University.

**Session C-2** **Longhorn Room**

# Climate Change

**1:35 PM**

## C-2.1 Refocusing Air Climate and Energy Policy for Cooler Cleaner Air

**Daniel Cohan**

Air quality management in the United States largely focuses on attaining air quality standards for criteria air pollutants, especially ground-level ozone "smog". However, since the ozone standard limits concentrations on the four most polluted days at the most polluted air quality monitor in each region, it drives abatement efforts toward control of peak ozone. Control of peak ozone does requires huge reductions in NOx emissions yielding little reduction in the average-day ozone levels which drive health impacts.

Meanwhile, global temperatures have warmed to their highest levels in recorded history as greenhouse gases continue to accumulate. Reductions in fossil fuel use and associated greenhouse gases can be achieved with substantial co-benefits for air quality.

This talk will show how efforts to reduce fossil fuel use via energy efficiency and renewable energy may offer a more constructive path to cooler, cleaner air than the traditional focus on pollutant-by-pollutant, region-by-region attainment planning.

**Presenter Biography:**
Daniel Cohan is an Associate Professor of Civil & Environmental Engineering at Rice University. He received his Bachelors in Applied Mathematics from Harvard University and Ph.D. in Atmospheric Sciences from Georgia Tech. He has served as a Fulbright Scholar to Australia, NSF CAREER Award recipient, and member of NASA's Air Quality Applied Sciences Team. He is an expert contributor to The Hill and author of columns for The Conversation and Houston Chronicle, along with more than 30 peer reviewed publications

**Session C-2** **Longhorn Room**

# EVA

**2:05 PM**

## C-2.2 Hypoxia in Space? What the Past tells us for the Future…

**James Wessel**

INTRODUCTION: Spacecraft for distant exploration will require a special atmospheric composition that balances flammability, mild hypoxia, and prevention of decompression sickness for crews undergoing extravehicular activities. This proposed exploration atmosphere for future manned missions is 8.2 psia and 34% oxygen (O2) (balance is nitrogen [N2]) [1,2]. This combination of factors (ppO2 = 144 mm Hg, PAO2 = 88 mm Hg) render an atmosphere that is nearly physiologically identical to the shuttle cabin condition while it was under the 10.2-staged prebreathe protocol (ppO2 = 140 mm Hg, PAO2 = 87 mm Hg). The 40 shuttle missions featuring this protocol provided a wealth of information for both comparison purposes and for setting expectations of suitability for manned exploration going forward as both atmospheres are mildly hypoxic and in the microgravity environment.
METHODS: A retrospective data mining exercise was undertaken to determine when the shuttle cabin depressed to 10.2 psia and repressed to 14.7 psia, as well as ppO2 and ppCO2 values for each of the shuttle flights that used the 10.2-psia staged prebreathe protocol. All these values were collected through the Archive Data Retrieval Interface Tool, a subprogram within NASA's Java Mission Evaluation Workstation System. For the astronauts' subjective reporting of possible hypoxia related symptoms (between 10.2 missions and 14.7 missions), private medical conferences and postflight debriefs were examined and pertinent nonattributable data were harvested and analyzed using logistic regression.
RESULTS: Over the entire Space Shuttle era, crewmembers experienced 132.8 days (782 man-days when adjusted for crew size) under the staged 10.2 condition (average 3.25 days per mission, maximum 8.1 days). For the physiologic gases, ppO2 averaged 2.75 ± 0.07 psia (142.2 ± 3.5 mm Hg) while depressed to 10.2, and 3.16 ± 0.13 psia (163.7 ± 6.4 mm Hg) at 14.7 psia before and after depress across all staged missions. The ppCO2 varied among the 10.2-psia shuttle missions, the average was 1.91 ± 0.6 mm Hg while depressed, and 2.07 ± 0.8 mm Hg at 14.7 psia. The maximum recorded ppCO2 was 11.02 mm Hg. There were 26 staged 10.2 shuttle missions with any recorded ppCO2 value above 4 mm Hg, and a notable 7 missions with ppCO2 at or above 7.6 mm Hg. Across all staged missions, 5.55% of all ppCO2 values were above 4 mm Hg, and 0.07% were above 7.6 mm Hg. Using logistic regression, 14 symptoms were analyzed with 10 resultant equations. None of the hypoxia symptoms were significantly associated with the 10.2-psia condition versus the 14.7-psia condition.
FORWARD WORK: Terrestrial experience indicates that chronic exposure to a comparable ppO2 of 140 mmHg is well-tolerated by healthy humans. The Space Shuttle experience indicated that similar levels of hypoxia in space resulted in no increased reporting of possible hypoxia related symptoms, and also there were no obvious crewmember performance issues related to completion of mission objectives. However, these results are only for shorter shuttle missions and it is unclear how chronic mild hypoxia interacts with physiologic changes due to microgravity over longer durations or if implemented later in a mission stage. Forward work will include examination of shuttle sleep logs (DSO 634) and future ground-based studies of the exploration atmosphere.
REFERENCES
[1] NASA/TP-2010-216134. The Final Report of the NASA Exploration Atmospheres Working Group.
[2] NASA/TM-2013-217377. J. R. Norcross et al.

**Presenter Biography:**
James Wessel is a contractor for Wyle Science, Technology & Engineering Group in support of the EVA Physiology Laboratory.

**Session C-2** **Longhorn Room**

# EVA

**2:35 PM**

## C-2.3 Finding Solutions to NASA's SpaceSuit Water Intrusions during EVA

**Keisha Antoine, PhD, PE and Yvonne Vigue-Rodi**

Astronauts who receive the singular privilege of flying in space on-board the International Space Station (ISS) rely on state-of-the-art technology and well-planned flight operations for their safety and well-being while working in space. NASA's Human Spaceflight Program places the highest priority on advancing space exploration while not comprising the safety of our astronauts. In this endeavor, NASA has developed pressurized spacesuits and in-flight extra-vehicular activity (EVA) operational procedures to ensure U.S. astronauts can explore and work safely in space. Therefore, an unexpected emergency situation, such as the recent ISS EVA spacesuit water intrusions, can directly threaten the safety of astronauts and force early curtailment of EVAs resulting in schedule slippage and the possible abort of critical repairs needed onboard the ISS. Publicly available information released by NASA's EVA Anomaly Resolution Team has been used to understand the problem and to propose ideas that can address the problem of spacesuit water intrusions. This information has been used to develop candidate solutions in anticipation they will lead to successful testing and integration into the current ISS U.S. spacesuits. Proven solutions are urgently needed to protect and ensure the safety of our astronauts to prevent further spacesuit water intrusion incidents so U.S. astronauts never experience any type of EVA spacesuit water intrusion incidents while working in space.

**Presenter Biography:**

Keisha Antoine obtained a B.S. in Chemical Engineering in 2001 and a M. Eng. and PhD in Materials Science & Engineering in 2004 and 2007, respectively, all from Lehigh University. She is the holder of one patent and is a registered professional engineer in the state of NY. Keisha has nearly 8 years of industrial experience working on glass processes and functionalization, carbon footprint and energy analyses at Corning Incorporated, a Fortune 500 technology company. In 2015, Keisha went into private practice and opened her own technical services consulting firm, Antoine Technical Consulting LLC, providing process design, scale-up and water management solutions to manufacturers principally in the chemical process industries. She is a current member of the American Institute of Chemical Engineers (AIChE).

Yvonne Vigue-Rodi received BS and MS degrees in Aerospace Engineering from the University of Texas at Austin. She spent 17 years at NASA JPL in Pasadena, California, developing advanced GPS technology for geophysics and oceanography from space. In 2007, Yvonne joined the ISS GN&C Team at Jacobs Technology in Houston, Texas, conducting ISS Assembly GN&C verification analysis for NASA JSC. In 2011, Yvonne founded Adelante Sciences Corporation in Houston, Texas, to develop advanced technology for the aerospace, defense and transportation industries.

# Systems Engineering

**1:35 PM**

## C-3.1 NASA Quantitative Risk Assessment Applied to the Oil & Gas Industry

**David Kaplan**

NASA has a world-class capability for quantitatively assessing the risk of highly-complex, isolated engineering structures operated in extremely hostile environments. In particular, the International Space Station (ISS) represents a reasonable analog for drilling and production operations on deepwater rigs. Through a long-term U.S. Government Interagency Agreement, the Bureau of Safety and Environmental Enforcement (BSEE) has partnered with NASA to modify NASA's Probabilistic Risk Assessment (PRA) capabilities for application to drilling and production operations on deepwater rigs. The immediate focus of the activity will be to modify NASA PRA Procedure Guides and Methodology Documents to make them applicable to the Oil & Gas Industry. The next step will be for NASA to produce a PRA for a significant drilling subsystem. Subsequent activities will be for NASA and industry partners to jointly develop increasingly complex PRA's for expanded rig systems, which includes both hardware and human reliability. The presentation will provide the objectives, schedule, and current status of PRA activities for BSEE.

**Presenter Biography:**
David Kaplan is a manager in the Safety and Mission Assurance (S&MA) Directorate with more than 30 years of experience in aerospace engineering and management. He has been a Project Manager for Mars hardware, a Space Shuttle flight controller, and managed the crew health care equipment on the International Space Station. Most recently, Mr. Kaplan served as Chief of the Quality & Flight Equipment Division (NT). He is currently the Business Development Lead for S&MA.

# Systems Engineering

**2:05 PM**

## C-3.2 Internet of Things at NASA

**Svetlana Hanson, James McClellan, Dave Kelldorf**

As the evolution of the Internet continues, there is a new wave of connected devices coming to market. These devices range from light bulbs, to thermostats, to wearables, to medical and industrial sensors. They will add significant functionality and value to our lives. Collectively this phenomenon has become known as the Internet of Things (IoT) or Internet of Everything. We look forward to the benefits these disruptive technologies will bring, and it is critical for us to understand the security implications.

Many of these devices are already appearing in our existing internal NASA networks today. Smart TVs, smart printers, Nest thermostats and wearables are examples of devices already in use. Most of these devices do not have adequate security built in and should be considered untrusted. This technology is becoming so pervasive that avoiding it will not be an option. Many of the things we buy will have IoT functionality built in. Therefore exposure to the risks these devices impose is automatic. It is imperative we understand and mitigate the risk. We must rethink and redefine all our architecture accordingly.

With that as a background, the Technology Infusion Branch of the OCIO Technology & Innovation Division started a Phase I investigation of IoT in the spring of 2015. The goal of the investigation was to better understand what IoT is and is not, learn the benefits and risks, and build a basis for NASA to properly meet the IoT challenge.

**Presenter Biography:**
Svetlana Hanson has over 20 years of experience in the software development field. Svetlana has worked on various projects to support Engineering and Center Operations Directorates. In 2014 Svetlana received JSC Exceptional Software Award for development of JSC Automated Badging System. Svetlana has been involved with AIAA over 10 years holding various positions on local and regional levels. Currently Svetlana Hanson is Deputy Director of Membership for Region 4 and counselor within Houston Section.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Human Exploration Spacecraft Testbed for Integration and Advancement

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The proposed topic will cover ongoing effort named HESTIA (Human Exploration Spacecraft Testbed for Integration and Advancement) lead at the National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) to promote a cross-subsystem approach to developing mars-enabling technologies with the ultimate goal of integrated system optimization. HESTIA also aims to develop the infrastructure required to rapidly test these highly integrated systems at a low-cost. The initial focus is on the common fluids architecture required to enable human exploration of mars, specifically between life support and in-situ resource utilization (ISRU) subsystems.

Due to the enormous mass gear-ratio required for human exploration beyond low-earth orbit, (for every 1 kg of payload landed on Mars, 226 kg will be required on Earth), minimization of surface hardware and commodities is paramount. Hardware requirements can be minimized by reduction of equipment performing similar functions though for different subsystems. If hardware could be developed which meets the requirements of both life support and ISRU it could result in the reduction of primary hardware and/or reduction in spares. Minimization of commodities to the surface of mars can be achieved through the creation of higher efficiency systems producing little to no undesired waste, such as a closed-loop life support subsystem. Where complete efficiency is impossible or impractical, makeup commodities could be manufactured via ISRU.

## ABSTRACT: Integrated Human-in-the-Loop Ground Testing – Value, History, and the Future

**Author: Don Henninger,** *Chief Technologist, Crew & Thermal Systems Division, Engineering Directorate, Johnson Space Center; Serves as the technical specialist for all Division core competencies including Space Suits, Environmental Control and Life Support, Thermal Control Systems, Crew Equipment and Habitability, Testing (including testing with humans in the loop), and Modeling and Analysis*.

Systems for very long-duration human missions to Mars will be designed to operate reliably for many years and many of these systems will never be returned to Earth. The need for high reliability is driven by the requirement for safe functioning of remote, long-duration crewed systems and also by unsympathetic abort scenarios. Abort from a Mars mission could be as long as 450 days to return to Earth. The key to developing a human-in-the-loop architecture is a development process that allows for a logical sequence of validating successful development in a stepwise manner, with assessment of key performance parameters (KPPs) at each step; especially important are KPPs for technologies evaluated in a full systems context with human crews on Earth and on space platforms such as the ISS. This presentation will explore the implications of such an approach to technology development and validation including the roles of ground and space-based testing necessary to develop a highly reliable system for long duration human exploration missions. Historical development and systems testing from Mercury to the International Space Station (ISS) to ground testing will be reviewed. Current work as well as recommendations for future work will be described.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Human Exploration System Test-bed for Integration and Advancement (HESTIA) Support of Future NASA Deep-Space Missions

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The Engineering Directorate at the NASA - Johnson Space Center is outfitting a 20-Foot diameter hypobaric chamber in Building 7 to support future deep-space Environmental Control & Life Support System (ECLSS) research as part of the Human Exploration System Test-bed for Integration and Advancement (HESTIA) Project. This human-rated chamber is the only NASA facility that has the unique experience, chamber geometry, infrastructure, and support systems capable of conducting this research.

The chamber was used to support Gemini, Apollo, and SkyLab Missions. More recently, it was used to conduct 30-, 60-, and 90-day human ECLSS closed-loop testing in the 1990s to support the International Space Station and life support technology development.

NASA studies show that both planetary surface and deep-space transit crew habitats will be 3-4 story cylindrical structures driven by human occupancy volumetric needs and launch vehicle constraints. The HESTIA facility offers a 3-story, 20-foot diameter habitat consistent with the studies' recommendations.

HESTIA operations follow stringent processes by a certified test team that including human testing. Project management, analysis, design, acquisition, fabrication, assembly and certification of facility build-ups are available to support this research. HESTIA offers close proximity to key stakeholders including astronauts, Human Research Program (who direct space human research for the agency), Mission Operations, Safety & Mission Assurance, and Engineering Directorate.

The HESTIA chamber can operate at reduced pressure and elevated oxygen environments including those proposed for deep-space exploration. Data acquisition, power, fluids and other facility resources are available to support a wide range of research.

Recently completed HESTIA research consisted of unmanned testing of ECLSS technologies. Eventually, the HESTIA research will include humans for extended durations at reduced pressure and elevated oxygen to demonstrate very high reliability of critical ECLSS and other technologies.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: HESTIA Phase I Test Results: The Air Revitalization System

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In any human spaceflight mission, a number of Environmental Control & Life Support System (ECLSS) technologies work together to provide the conditions astronauts need to live healthily, productively, and comfortably in space. In a long-duration mission, many of these ECLSS technologies may use materials supplied by In-Situ Resource Utilization (ISRU), introducing more interactions between systems. The Human Exploration Spacecraft Test-bed for Integration & Advancement (HESTIA) Project aims to create a test-bed to evaluate ECLSS and ISRU technologies and how they interact in a high-fidelity, closed-loop, human-rated analog habitat. Air purity and conditioning are essential components within any ECLSS and for HESTIA's first test they were achieved with the Air Revitalization System (ARS) described below.

The ARS provided four essential functions to the test-bed chamber: cooling the air, removing humidity from the air, removing trace contaminants, and scrubbing carbon dioxide ($CO_2$) from the air. In this case, the oxygen supply function was provided by ISRU. In the current configuration, the ARS is a collection of different subsystems. A fan circulates the air, while a condensing heat exchanger (CHX) pulls humidity out of the air. A Trace Contaminant Removal System (TCRS) filters the air of potentially harmful contaminants. Lastly, a Reactive Plastic Lithium Hydroxide (RP-LiOH) unit removes $CO_2$ from the breathing air.

During the HESTIA Phase I test in September 2015, the ARS and its individual components each functioned as expected, although further analysis is underway. During the Phase I testing and in prior bench-top tests, the energy balance of heat removed by the CHX was not equal the cooling it received. This indicated possible instrument error and therefore recalibration of the instruments and follow-up testing is planned in 2016 to address the issue. The ARS was tested in conjunction with two other systems: the Human Metabolic Simulator (HMS) and the Electrolyzer. They behaved as anticipated as well. The HMS added humidity, $CO_{2,}$ and heat to the chamber while removing oxygen, and the Electrolyzer (an ISRU technology) added oxygen.

The objective for HESTIA in 2015 was achieved: the creation of a high-fidelity test-bed for ECLSS and ISRU technologies. With the 'backbone' technologies installed, more technologies will be added to increase the analog habitat's fidelity over the next few years. The ARS was designed with this in mind, and as new technologies develop and mature, the strategic installation of the existing components will allow for them to be replaced with the new technologies.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Liquid Oxygen / Liquid Methane Propulsion Brassboard for Future Sounding Rocket Testing

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Human-Mars architectures point to an oxygen-methane propulsion economy utilizing common commodities, scavenged from the planetary atmosphere and soil via In-Situ Resource Utilization (ISRU). Although liquid oxygen / liquid methane (LOx/LCH4) propulsion technologies have advanced significantly over the past decade, an in-space ignition of the propellant combination has yet to be achieved. This topic outlines the initial grass-roots effort to do just that. A brassboard integrated system propulsion system approximately the size which could be integrated onto a sounding rocket is currently under development at the NASA Johnson Space Center (JSC) Propulsion & Power Division.

The topic will outline the innovative development of the brassboard using rapid prototyping to reduce cost and increase development pace of the design and manufacturing process. The topic will also cover the integrated operations with a solid oxide fuel cell (SOFC), specifically the propellant conditioning approach and outlining of future integration concerns between power and propulsion.

## ABSTRACT: Mars ISRU; Water Production from JSC-Mars-1A

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As NASA pursues sending humans to Mars, the need for self-sustaining technologies becomes essential. Water and oxygen are vital to support life and oxygen (and methane) offer an ideal propellant. Rather than transporting those consumables from Earth, NASA is investigating methods of extracting water, found globally across the surface, from the Martian regolith. The Martian regolith can be harvested and heated to release the water. The water can then be cleaned for human consumption or further processed via electrolysis to produce oxygen and hydrogen. Recently, NASA has been studying the liberation of water from simulated regolith. An in-house vertically agitated type dryer (aka Sandman) developed, for hydrogen reduction of lunar simulant, under the Outpost Precursor Testbed for ISRU and Modular Architecture (OPTIMA) project in 2007 was repurposed for Martian water extraction testing, under the Human Exploration Spacecraft Testbed for Integration and Advancement (HESTIA) project. JSC-Mars-1A (Martian simulant) was heated in the presence of $N_2$ or $CO_2$ and the water evolved was captured, measured and analyzed.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Solid Oxide Fuel Cell Testing at JSC

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Human-Mars architectures point to an oxygen-methane economy utilizing common reactants, scavenged from the planetary atmosphere and soil via In-Situ Resource Utilization (ISRU), and common tankage. NASA can greatly decrease the volume and mass of materials on Mars by increasing commonality between Mars subsystems, such as power, propulsion, and life support. Solid Oxide Fuel Cells (SOFCs) and LOx/$LCH_4$ propulsion are included in NASA roadmaps as necessary technologies for furthering human exploration towards Mars within this integrated system architecture.

NASA's Johnson Space Center has begun efforts to integrate a space-like (air-independent) SOFC system with multiple ISRU/lander components to mimic Mars operations. Of particular interest this past year, JSC's Propulsion and Power Division has begun the work of integrating a fuel cell into an oxygen-methane lander propulsion system by preparing to run an SOFC off of cryogenically stored oxygen. In the past, spacecraft power and propulsion systems have utilized separate reactant/propellant tanks; however, shared power and propulsion oxidizer/fuel tanks decreases vehicle complexity and mass.

Further, previous space-rated fuel cells (for Gemini, Apollo, and Space Shuttle) required high purity hydrogen and the quality of reactants created by ISRU systems on Mars is insufficient for these technologies. Due to their high operating temperature, SOFCs might be capable of using ISRU-produced methane to make power and water; however, they have never been tested for space application. JSC's Propulsion and Power Division plans to continue its work on steam methane reformation to provide a hydrogen-rich stream of gas, along with cryogenic oxygen, to the SOFC in a full vehicle-like test to assess SOFCs for future spaceflight applications.

The data in this presentation will encompass testing done at JSC, including running a "space power profile" on an SOFC for the first time. This work will lay the foundation for NASA's next planetary lander.

## ABSTRACT: Steam Methane Reformation Testing for Air-Independent Solid Oxide Fuel Cell Systems

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Recently, NASA has been looking into utilizing landers that can be propelled by LOX-$CH_4$, to be used for long duration missions. Using landers that utilize such propellants, also provides the opportunity to use solid oxide fuel cells as a power option, especially since they are able to process methane into a reactant through fuel reformation. One type of reformation, called steam methane reformation, is a process to reform methane into a hydrogen-rich product by reacting methane and steam (fuel cell exhaust) over a catalyst. A steam methane reformation system could potentially use the fuel cell's own exhaust to create a reactant stream that is hydrogen-rich, and requires less internal reforming of the incoming methane. Also, steam reformation may hold some advantages over other types of reforming, such as partial oxidation (PROX) reformation. Steam reformation does not require oxygen, while up to 25% can be lost in PROX reformation due to unusable CO2 reformation. NASA's Johnson Space Center has conducted various phases of steam methane reformation testing, as a viable solution for in-space reformation. This has included using two different types of catalysts, developing a custom reformer, and optimizing the test system to find the optimal performance parameters and operating conditions.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Liquid Oxygen / Liquid Methane Propulsion Brassboard for Future Sounding Rocket Testing

***Brian Banker****, NASA, Johnson Space Center, Houston, TX 77058, USA*
*Engineer, Propulsion Systems Branch, EP4, AIAA Member*

Human-Mars architectures point to an oxygen-methane propulsion economy utilizing common commodities, scavenged from the planetary atmosphere and soil via In-Situ Resource Utilization (ISRU). Current ISRU technologies produce rocket propellants (oxygen and methane) in gaseous forms; however, these commodities must be liquefied for efficient storage and consumption by a rocket engine. To date, little work has been performed on the liquefaction task. Although some aspects of in-space cryogenic storage apply, high-efficiency liquefaction on the surface of a planetary body is a unique, system specific problem which must be solved to enable the full potential of ISRU.

The topic will cover the various refrigeration cycles, cooling configurations possible as well as current testing being performed at the NASA Johnson Space Center as well as work across NASA.

## ABSTRACT: Mars ISRU; Water Production from JSC-Mars-1A

***Author: Pooja Desai,*** *NASA, Johnson Space Center, Houston, TX 77058, USA*
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The spacesuits for missions beyond Low Earth Orbit (LEO) need to be lighter than the Extra-vehicular Mobility Units (EMUs) used on Shuttle and the International Space Station (ISS) due to a large mass gear ratio. They also need to be less complex to increase reliability. In the Portable Life Support System (PLSS) on the EMUs, high pressure gaseous oxygen (GOX) is stored at 3,000 psia to provide breathing air for the astronaut during an extravehicular activity (EVA). One area that can be redesigned is the system used to fill the pressure vessels the GOX is stored in.

Currently, compressors are used to compress low pressure GOX to higher pressures and then fed into the PLSS oxygen tanks. However, compressors have moving parts that add complexity to a system and may not be reliable enough for advanced missions. One alternative is to generate high pressure oxygen from cryogenic source. For missions such as Mars exploration, in-situ resource utilization is expected to provide enormous quantities of cryogenic oxygen for the Mars Ascent Vehicle (MAV). A small quantity of cryogenic oxygen can be drawn from this large source for EVA applications.

In this system, the cryogenic oxygen would be gasified in a servicing tank and then transferred to the PLSS. Cryogenic oxygen reduces the mass of tankage required for oxygen storage and the gasifying process has high reliability because there are no moving parts involved.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Commodities Exchange Pallet (CEP)

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The Commodities Exchange Pallet (CEP) is a project being developed as part of the NASA Human Exploration Spacecraft Testbed for Integration and Advancement (HESTIA) focused on demonstration and evaluation of multi-system integration for future human deep-space exploration missions.

For beyond low earth orbit (LEO) human planetary exploration, In-Situ Resource Utilization (ISRU) could be capable of producing sufficient oxygen and water to be consumed for crew life support. However, the distance between an ISRU unit and the human habitat could be upwards of 1 km, making the transfer of such commodities difficult.
A proposed solution is the use of the Commodities Exchange Pallet (CEP). The CEP is a pallet- mounted system, which could collect resources (water and oxygen) produced by the ISRU plant and transport them via rover to the crew habitat for consumption. Multiple pallets could be implemented eliminate down-time during transportation and to increase reliability.

Currently, a prototype is being developed as for evaluation of integration between systems. Ultimately, the lessons learned from this prototype will be leveraged to produce more flight-like version.

## ABSTRACT: Using an Integrated Distributed Test Architecture to Develop an Architecture for Mars

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The creation of a crew-rated spacecraft architecture capable of sending humans to Mars requires the development and integration of multiple vehicle systems and subsystems. Important new technologies will be identified and matured within each technical discipline to support the mission. Architecture maturity also requires coordination with mission operations elements and ground infrastructure. During early architecture formulation, many of these assets will not be co-located and will required *integrated, distributed test* to show that the technologies and systems are being developed in a coordinated way. When complete, technologies must be shown to function together to achieve mission goals. In this presentation, an architecture will be described that promotes and advances integration of disparate systems within JSC and across NASA centers.

# Human Exploration Spacecraft Testbed for Integration & Advancement (HESTIA)

## ABSTRACT: Water Electrolysis for In-Situ Resource Utilization (ISRU)

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Sending humans to Mars for any significant amount of time will require capabilities and technologies that enable Earth independence. To move towards this independence, the resources found on Mars must be utilized to produce the items needed to sustain humans away from Earth. To accomplish this task, NASA is studying In Situ Resource Utilization (ISRU) systems and techniques to make us of the atmospheric carbon dioxide and the water found on Mars. Among other things, these substances can be harvested and processed to make oxygen and methane. Oxygen is essential, not only for sustaining the lives of the crew on Mars, but also as the oxidizer for an oxygen-methane propulsion system that could be utilized on a Mars ascent vehicle. Given the presence of water on Mars, the electrolysis of water is a common technique to produce the desired oxygen. Towards this goal, NASA designed and developed a Proton Exchange Membrane (PEM) equipped water electrolysis system that was slated to produce oxygen for propulsion and fuel cell use in the Mars Atmosphere and Regolith COllector/PrOcessor for Lander Operations (MARCO POLO) project. As part of the Human Exploration Spacecraft Testbed for Integration and Advancement (HESTIA) project, this same electrolysis system, originally targeted at enabling in situ propulsion and power, operated in a life-support scenario. During HESTIA testing at Johnson Space Center, the electrolysis system supplied oxygen to a chamber simulating a habitat housing four crewmembers. Inside the chamber, oxygen was removed from the atmosphere to simulate consumption by the crew, and the electrolysis system's oxygen was added to replenish it. The electrolysis system operated nominally throughout the duration of the HESTIA test campaign, and the oxygen levels in the life support chamber were maintained at the desired levels.

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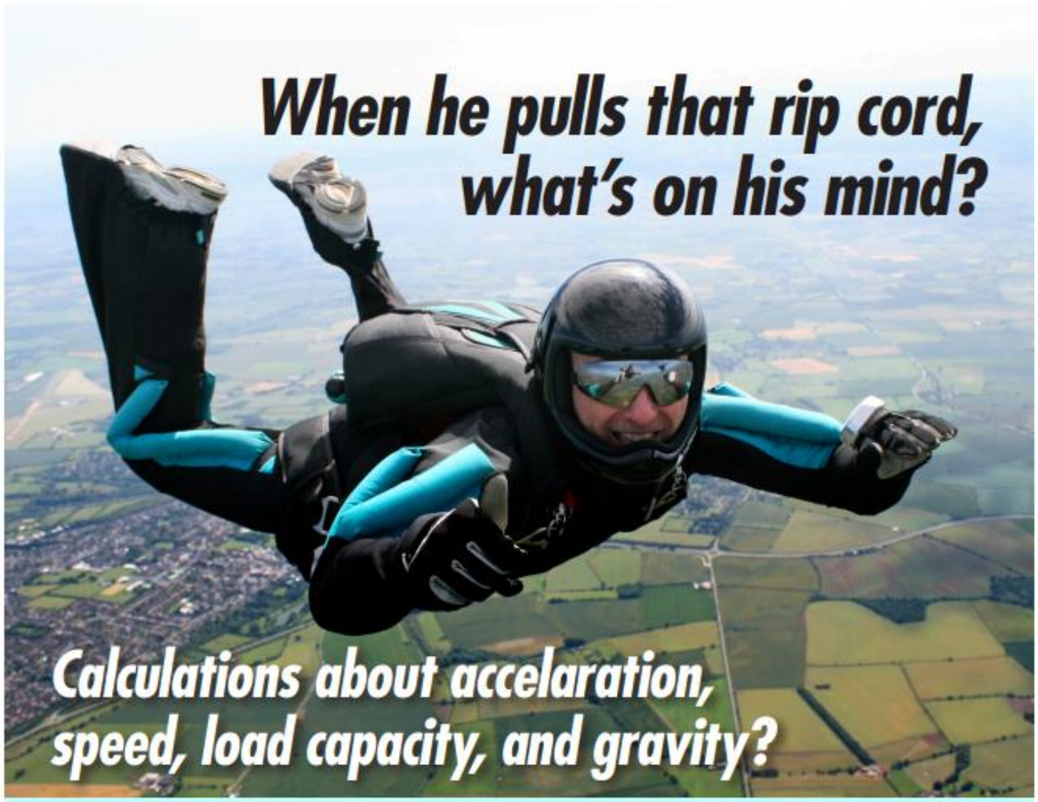


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