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# REVOLUTIONARY AEROSPACE SYSTEMS CONCEPTS ACADEMIC LINKAGES (RASC-AL)

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**Abstract**

Future exploration missions in the space between the Earth and the Moon or beyond will require complex operational activities to ensure that crew, cargo, and exploration systems safely and successfully reach their destination. Through the Revolutionary Aerospace Systems Concepts - Academic Linkage (RASC-AL) competition, NASA partners with the National Institute of Aerospace to bring together university teams to design human scale deep space architecture concepts. Engaging academia allows NASA to obtain innovative approaches and harnesses the ingenuity of university students to bring forth revolutionary new ideas that have influenced current and future human space exploration planning.

RASC-AL is an annual university-level (undergraduate and graduate) student design competition that seeks innovative approaches to NASA's future engineering and technology advancement needs related to extending humanity's reach beyond low Earth orbit. Over the course of an academic year, university teams design human scale architecture concepts that have supporting engineering analysis and realistic assessment of costs for technology maturation, system development and operations. Through a rigorous 2 gate down-select process, 12 to 16 teams are chosen to advance to present their concepts to a panel of NASA and industry judges at the annual RASC-AL Forum in Cocoa Beach, Florida. The forum provides students a once-in-a-lifetime opportunity to engage in conversations with NASA and industry experts, and many students have received job/internship offers based on their participation. The RASC-AL themes encourage students to develop concepts for space pioneering and prospecting toward Earth independence, which are critical to achieve NASA's goal of extending humanity's reach into space.

Since 2009, NASA has received 290 RASC-AL student concepts from 132 universities that address topics such as orbital debris mitigation approaches, tele-operated robotics, artificial gravity deep space transports, reusable hybrid propulsion, and in-situ drilling operations. These concepts provide NASA with novel and robust applications to support expanding humanity's ability to thrive beyond Earth.
**Keywords:** systems engineering, university, partnerships, education, spaceflight architecture, challenge

**Acronyms/Abbreviations**

Revolutionary Aerospace Systems Concepts - Academic Linkage (RASC-AL), International Space Station (ISS), National Aeronautics and Space Administration (NASA), Space Policy Directive 1 (SPD-1), Advanced Exploration Systems (AES), Space Launch System (SLS), National Institute of Aerospace (NIA), Notice of Intent (NOI), Pioneering Exceptional Achievement Concept Honor (PEACH), Science, Technology, Engineering and Mathematics (STEM).

## 1. Introduction

Established in 1958 by Congress through the National Aeronautics and Space Act of 1958, NASA has been devoted to the peaceful exploration of space for the benefit of all humankind. One objective of the Space Act was the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes [1].

For over 60 years, NASA has been conducting a robust human space program in low Earth orbit. While establishing a permanent presence in low Earth orbit aboard the International Space Station (ISS), NASA has been developing an architecture and the technology necessary to extend human presence deeper into space and to the Moon for sustainable long-term exploration. Along the way NASA has engaged the higher education community to contribute to NASA's in exploration and discovery. NASA's Advanced Exploration Systems (AES) division develops strategic partnerships and collaborations with universities to help bridge gaps and increase knowledge in architectural design trades, capabilities, and technology risk reduction.

NASA AES introduced the RASC-AL Challenge as a university-level competition to develop real world aerospace design concepts. The students design innovative solutions to human spaceflight architecture problems. The project and topics evolve with NASA's human spaceflight architecture studies. For example, in 2011 when NASA's mission was focused on planning the Asteroid redirect mission and the evolvable Mars architecture , the RASC-AL themes were Near-Earth Object (NEO) Flexible Mission Architecture Designs and Technology-Enabled Human Mars Mission [2].

In December 2017, the U.S. Presidents signed the Space Policy Directive 1 (SPD-1) directing NASA to "Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations;"[3]. As NASA began to develop the architecture in response to SPD-1, the RASC-AL theme for 2018 was Lunar Polar Sample Return. Challenging team to design a scalable tele-operated robotic architecture that would enable a sample return from the lunar polar region to the NASA's Gateway [4].

In 2020, 15 teams will be chosen to compete at the RASC-AL Forum in Cocoa Beach, Florida on topics covering a lunar South Pole Multi-Purpose Rover and a Commercial Cislunar Space Development providing a synergistic approach to a sustainable presence on the lunar surface [5].

## 2. Approach

NASA has a rich history of developing educational initiatives that offer students a unique opportunity to engage in the Agency's mission to meet. NASA's Strategic Plan outlines the following goals and objectives that are appropriate areas of contribution by RASC-AL projects:

Strategic Goal: Extend human presence deeper into space and to the Moon for sustainable long-term exploration and utilization.

- *Objective 2.1*: Lay the Foundation for America to Maintain a Constant Human Presence in Low Earth Orbit Enabled by a Commercial Market.
- *Objective 2.2*: Conduct Exploration in Deep Space, including to the Surface of the Moon.

Strategic Goal: Address National Challenges and Catalyze Economic Growth.

- *Objective 3.3*: Inspire and Engage the Public in Aeronautics, Space, and Science.

Strategic Goal: Optimize Capabilities and Operations.

- *Objective 4.1*: Engage in Partnership Strategies [6].

NASA's AES division, the sponsor of the RASC-AL Challenge, pioneers new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond low-Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space and are strongly coupled to future human spaceflight architecture development. AES has five objectives for the RASC-AL Challenge:

1. Enables students to learn by putting into practice the knowledge and skills they gained throughout their academic career.
2. Provides a mechanism for students to analyze and solve complex design and integration issues from an interdisciplinary perspective.
3. Offers students the opportunity to exerce their innovation skills and initiative as they deal with conflicting requirements and make appropriate trade-offs.
4. Teams will develop skills in project planning, teamwork, leadership, critical thinking, and decision-making in an academic environment, but with an eye toward integration with NASA activities.
5. Teams will develop a final product that may include a study or test article or both and a final report that will be made widely available to space agencies, aerospace companies, and universities.

The National Institute of Aerospace (NIA) is a nonprofit research institute create to conduct leading-edge aerospace research, develop new technologies and help inspire the next generation of scientists and engineer [7]. NASA partners with the NIA to implement the RASC-AL Challenge to increase knowledge of exploration mission architectures, capabilities and/or technologies related to future human spaceflight missions. The competition provides a mechanism to obtain innovative, unique and/or synergistic advanced concepts and engineering analysis. Previous RASC-AL project submissions have been incorporated into NASA human spaceflight architectures.

Finally, this project advances the nation's science, technology, engineering and mathematics (STEM) education pipeline by providing students the opportunity to engage in real space mission architecture design, gaining valuable experience that will extend to their professional careers, strengthening NASA and the nation's future technical workforce.

## 3. Methods

NIA in collaboration with NASA releases an annual call for proposals prior to each academic year for a university-based team challenge to develop new concepts that leverage innovations to improve our ability to operate in space and in deep space. University graduate and undergraduate teams led by a designated faculty advisor responds by choosing a theme which aligns to their interests and expertise. University teams submit RASC-AL proposals which are reviewed by a technical panel of judges from NASA and industry. Selected teams mature their submissions and resubmit them for a second down select process to determine which teams will be invited to the RASC-AL symposium. Teams invited to compete at the symposium receive a monetary award to facilitate participation in the symposium. At the symposium, teams give a 30-minute oral presentation and present a poster or prototype and are evaluated by a panel of expert judges from industry. The top two overall winning teams are awarded a $6,000 travel stipend present their concept at and aerospace conference.

### *3.1 Theme Selection*

Teams develop architectural studies and prototypes in response to themes identified by members of NASA's human spaceflight architecture team. Themes selected are relevant to current system architecture needs.

For example, in 2018 NASA began work with commercial and international partners to develop the Gateway, a small spaceship that will be placed in orbit around the Moon that will provide access to the lunar surface. The Gateway will serve as a lab for science and research, ports for visiting spacecraft and a transfer point to the lunar surface. To support these efforts, the 2019 RASC-AL themes selected were:

- Theme 1 Gateway Logistics as a Science Platform: This theme challenged teams to propose use cases for the Gateway logistics module as a science platform. Submissions identified measurements that could be retrieved using the capabilities of the logistics module. Teams also identified potential instrument concepts that could be supported by the logistics module to perform the desired science. Teams were required to describe the concept of operations for their science payload, from launch to arrival at the Gateway, as well as any relevant operations after the logistics module leaves the Gateway. Teams identified the science that will be performed and why it was selected. Teams described how their science payload fits within the provided capabilities of the logistics module identified what new technical capabilities are required to enable their science payload, keeping in mind NASA's human exploration timeline and strategic principle of fiscal realism.
- Theme 2 Gateway-based Cis-lunar Tug: This theme challenged teams to design a reusable cis-lunar tug to transport payloads between the Gateway and low Lunar orbit. The tug needed to be reusable and refuellable at the Gateway and be capable of transporting non-crewed payloads, to include lunar sample return payloads, other science platforms, landers, and commercial assets. Teams were required to describe the concept of operations for their tug, from initial deployment, to payload transfer modes, including identifying capabilities to transfer payloads to other destinations besides low Lunar orbit (e.g., Lagrange points). Teams describe the designs of the tug, including mass, power, geometry, and necessary technical capability developments, keeping in mind the tug's 2025 operational date. Teams identified relevant use cases for the tug, and the frequency with which the tug could support those use cases. Teams also described the concept of operations for refueling the tug, and determined the likely lifetime of the system prior to needing replacement.
- Theme 3 Gateway-based Human Lunar Surface Access: This theme challenged teams to come up with concepts for crewed lunar surface access and a campaign that allows repeated surface missions to establish a research station at or near one of the Moon's poles. The architecture leveraged current NASA capability investments, as well as existing or anticipated (near-term) commercial and international launch vehicles, in space propulsion capabilities, and lunar surface systems. The plan had to have the crew delivered from Earth to the Gateway using NASA's Space Launch System (SLS) and Orion with the crew returning to Earth from the Gateway via Orion. The architecture was to be open ended to facilitate evolution from the initial capability to a model that leverages commercial services in order to reduce costs for sustained crew access to the lunar surface.
- Theme 4 Gateway Uncrewed Utilization & Operations: This theme challenges team to design utilization scenarios and systems concepts addressing those scenarios for the 11 month uncrewed Gateway period. These scenarios addressed automated logistics management, critical fault detection and maintenance, supportable science, technology demonstration and commercial applications in the absence of crew being on the Gateway. Implications on Gateway systems such as environmental control, computing, robotics, communications, power and thermal needed to be assessed. Crew activities just prior to leaving the Gateway and upon initially returning to the Gateway needed to support the uncrewed period should were assessed. Teams were to assume

approximately one month of Gateway reconfiguration/stabilization/system evaluation preceding the crew arrival while two weeks are necessary to return to uncrewed operational status [4].

*3.2 Submission Process*

Each August, NASA and NIA invites teams of undergraduate and graduate students majoring in science, technology, engineering, or mathematics at an accredited United States based university to develop new concepts to improve our ability to operate in deep space. Teams must contain, one faculty or industry advisor and at least two students. The advisor is required to attend the competition. RASC-AL is open to foreign students or universities that participate as team members or collaborators on a U.S. led team. Teams are categorized as undergraduate or graduate by the majority composition of the team.

Table 1. Proposal Phase Timeline

| | |
|---|---|
| August | Release of Request for Proposals |
| October | Notification of Intent deadline |
| October | Questions for Technical Interchange due |
| Early March | Proposals and Videos due |
| Late March | Symposium Selections Announcements |
| May | Technical Papers Due |
| June | Symposium |

Interest teams are encouraged but not required to submit a Notice of Intent (NOI) to allow the project to plan for an adequate number of proposal reviewers. As an incentive to teams to submit an NOI, they are provided the opportunity to participate in a question and answer sessions with the competition judges before the proposal due date. NOIs are required to provide the following information: university names; team category; partnering universities (if any); themes chose; advisor and team lead contact information; and synopsis or their concept. NOIs are not considered in the judging process.

In early March, teams submit a 7-9 page proposal and accompanying video. The proposal articulates the innovation or design being proposed including any planned engineering analysis or current progress. It should provide the scope of the planned final paper if selected to attend the final competition. Proposals include:

- University name and Project title
- Full names of all team members including course of study and academic level
- Graphic or image of concept
- Identification of the Theme Requirements and how each was addressed
- Innovative approaches, capabilities or technology
- Detailed information on trades, concepts, and mission constructs.
- Why the design, configuration, system or approach was chosen in relation to technology readiness, system performance, affordability, programmatic implementation and risk.
- Original analysis and engineering
- Key findings to support approach
- Technology assumptions
- Budget Assessment
- Project timeline

Teams are also required to submit a two-minute video to augment's the team's proposal. The video can include animation, graphics, or other creative ways to showcase their concept [8].

*3.3 Forum Selection Process*

After the proposals are received, the judging panel conduct a thorough review and ranks the submissions. The panel is comprised of experts from NASA and industry partners such as Cislunar Space Development company, SpaceWorks, AST & Science, Blue Origin, SpaceX, Boeing and Aerojet Rocketdyne. The proposals are evaluated using a published Proposal Evaluation Criteria (see Table 2).

Table 2. Proposal Evaluation Criteria

| | |
|---|---|
| Adherence to RASC-AL themes and mission objectives as stated in the relevant theme description | 10 pts |
| Synergistic application of innovative approaches, capabilities and/or new technologies for evolutionary architecture development to enable future missions, reduce cost, or improve safety | 15 pts |
| Sound technical / scientific / engineering analysis, evaluation and rationale of mission concept | 15 pts |
| Evidence of thorough and proper research conducted | 15 pts |
| Key findings support the envisioned approach | 15 pts |
| Realistic preliminary budget assessments | 15 pts |
| Realistic technology assumptions | 15 pts |

Selected teams are invited to compete in the RASC-AL Forum which is held in Cocoa Beach, Florida in June. Teams choosing to participate in the forum receive a travel stipend in the amount of $6,000 to facilitate their participation in the forum.

*3.4 RASC-AL Forum and Competition*

Teams selected to compete in RASC-AL Form are required to submit a fifteen-page technical report and depending on the theme selected prepare a poster or prototype to be presented at the forum. In the development of the paper the students are provided various resources to guide their technical design including: NASA Human Integration Design Handbook and Processes, Cost Estimating Handbook and Software and NASA's Systems Engineering Handbook. Over a three-day period, each team is given 30 minutes to present their concept with an additional 10 minutes for questions and answers. Additionally, each team is given a table to display a 48"x36" poster, a demonstration or prototype of their concept. The team's evaluation of their oral presentation and poster make up 35 percent of the team's overall score with the technical paper score is the remaining 65 percent. The evaluation criteria is shown in the Forum Evaluation Criteria (see Table 3).

Table 3. Forum Evaluation Criteria

| **Technical Paper/Written Criteria** | **Point Scale** |
|---|---|
| Adherence to RASC-AL themes and mission objectives as stated in the theme descriptions | 10 |
| Innovative, unique and/or synergistic advanced concepts and engineering analysis, and applications to enhance the exploration mission, architectures, capabilities, and/or technologies | 20 |
| Technical merit and rationale of mission concept; understanding of technical challenges | 25 |
| Realistic assessment of project cost/schedule | 10 |
| **Total Possible Points – Written Criteria** | **65** |
| **Presentation & Poster/Demonstration Session Evaluation Criteria** | **Point Scale** |
| Oral presentation quality and consistency with technical paper | 10 |
| Presence of teamwork and integration | 10 |
| Quality of response to questions for presentation and poster, models and prototypes | 10 |
| **Total Possible Points – Presentation & Poster/Demonstration Session Criteria** | 30 |
| **Forum Participation** | **Point Scale** |
| Attendance and engagement in all Forum activities | 5 |
| **Total Possible Points – Forum Participation** | **5** |

In addition to the oral presentation and poster sessions students also participate in a number of professional development and social activities during the forum. Networking and recruiting events allow the students to interact with NASA and industry representatives which provides potential for internships or post-graduation employment. NASA leadership provides briefings on the current status of NASA's deep exploration plans and students are given a tour or Kennedy Space Center to view current technology and infrastructure development efforts.

*3.5 Winners and Prizes*

One winning team is selected from the undergraduate category and one winning team is selected from the graduate category. Additionally, recognition is awarded in each theme for Best in Theme and The Pioneering Exceptional Achievement Concept Honor (PEACH) Award is presented to the most innovative idea or meaningful concept as presented at the forum as determined at the discretion of the judges. The top two overall winning teams are provided travel stipends to present their concept at a future professional aerospace conference.

## 4. Results

Each year, the RASC-AL Competition provides approximately 200 to 300 undergraduate and graduate students at higher education institutions the opportunity to work collaboratively and incorporate their coursework into real engineering design concepts. Participants spend 24 to 40 in-person contact hours in the development of their final product. Over the past 11 years, 179 teams from 50 unique universities from 27 states have participated in RASC-AL. During that period over 1,000 university students have presented their research to judges from the aerospace industry.

Fig. 1. U.S. University Participation in RASC-AL

In 2019, the RASC-AL Competition participated in a study commissioned by NASA's Office of STEM Engagement to understand how NASA STEM programs are meeting the scientific and technical needs of the agency. The study was used to obtain knowledge about how the selected projects contribute to NASA's aeronautics, space, and science missions, as well as align to evidence based effective practices for STEM learning. The study found:

*"The RASC-AL activity is a higher education competition that invites multi-disciplinary and multi-university student teams to engage with NASA missions and experts. The activity allows students to incorporate their coursework into real aerospace design. RASC-AL produces a number of benefits for NASA including producing innovative engineering and analysis that explores trade-space scenarios that can be included in NASA program planning. Additionally, the activity increases knowledge in areas related to NASA workforce needs and strengthens the future STEM workforce. Although not designed to fit evidence-based practices for STEM learning, the activity is an authentic STEM experience that is characterized by many of the high-quality practices seen in the research literature [9]."*

The study found that RASC-AL participants gain practical work experience and produce STEM workforce relevant products throughout the competition which contributes to a "workforce ready pipeline." With the competition tailored on a yearly basis to align directly with NASA's AES division human spaceflight architecture efforts, the results immediately reviewed for applicability for current NASA studies. Below are three examples solutions.

As a 2019 participant, the University of Puerto Rico at Mayaguez conducted provided a solution for the "Gateway-based Human Lunar Surface Access Theme. The Lunar Exploration and Access to Polar Regions (LEAPR) study provided an architecture to meet an extensive lunar campaign. They designed a single stage reusable lander (see Fig. 1) that could sustain one annual crewed mission to the Moon for a minimum of 15 years. It utilized both NASA and commercial launch capabilities as well as the Gateway [10].

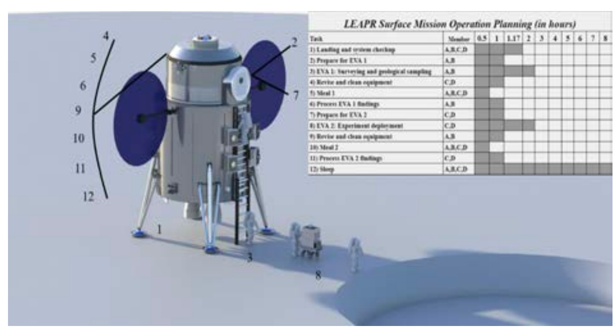

Fig. 2. University of Puerto Rico at Mayaguez Karaya Transport Vehicle

In 2018, the Colorado School of Mines selected the "Polar Sample Return Architecture" theme and designed the Polar Sample Extraction In-Situ Drilling Operations Network (POSEIDON). POSEIDON was concept for tele-operated sample return operations from the lunar surface to a crewed station in the lunar orbit. Their Multi-purpose Ascent and Return Vehicle (MARV) had an external cargo bay with a 10-sided, pyramidal, external cargo platform. The platform could hold Drilling Extraction Transport Robots (DEXTR) which are deployable rovers that are guided telerobotically wit automated obstacle rerouting [11].

Fig. 3. Colorado School of Mines Polar Sample Extraction In-Situ Drilling Operations Network

The final example is from 2017, the University of Maryland College Park designed a modular space station to support four crew members with a minimum 15-year life span and is configurable for multiple mission scenarios. This was in response to the Commercially Enabled LEO/Mars Habitable Module and included an airlock, robotic arm, internal layout, power generation, propulsion, thermal control, guidance, navigation and control as well as communications. In order to test the interior of the module layout, a mock-up of the interior with two of the alcoves was built and tested in the university's Neutral Buoyancy Research Facility. Data collected during the test were used to modify the design for improved astronaut operation [12].

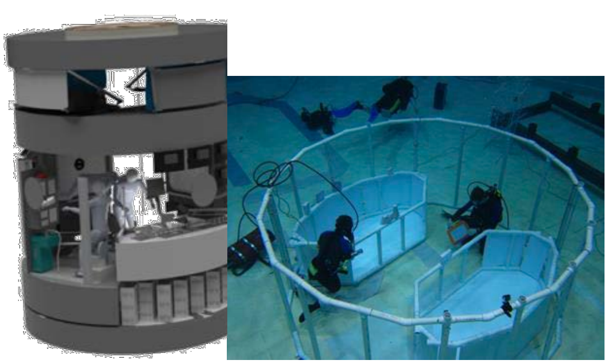

Fig. 4. University of Maryland College Park Ultima Thule Design

Along with the technical knowledge gained, the students also learn valuable lessons that can be applied in their future careers.

- Read and follow all guidelines and requirements.
- Do solid research and not restate information found on internet searches.
- Use the technical resources provided.
- Find a balance between sound technical analysis and revolutionary concepts.
- Provide analysis and documentation of your expected outcomes.
- Be sure your math, science and engineering fundamentals are solid.
- Ensure your models contains realistic numbers.
- Utilize the principles of Project Management.
- If you don't know the answer, don't answer the question.

As a result of participation in RASC-AL, NASA and commercial aerospace partners have hired both interns and employees from connections made during the RASC-AL Forums. This includes the current vice president and Director or Exploration Technology at Honeybee Robotics, a company selected to provide drilling, coring and sampling technologies for planned lunar and Mars missions.

## 6. Conclusions

RASC-AL provides an opportunity for multi-disciplinary higher education student teams to engage in the engineering design process and provides a high-quality learning experience for participants. The students develop solutions to design challenges and compose and present technical papers for both non- peer and peer reviewed publication that contributes to the United States overall technical capability while strengthening the future science, technology, and engineering workforce.

The results provide the human spaceflight community with rigorously developed concepts, original engineering and analysis that includes innovative new thinking and concepts that explore trade-space scenarios that can be included in NASA program planning. It provides the next generation of human exploration science and engineering workforce with a rigorous and relevant opportunity to compete with top teams across the nation and to engage directly with leaders in the space exploration community of practice.

Finally, the RASC-AL competition provides NASA with novel ideas that address NASA mission needs and provides a low-cost mechanism for the development of architectural studies or test articles that helps to advance NASA's deep space human spaceflight goals and objectives.

## References


[1] United States Congress, National and Commercial Space Programs Act (51 U.S.C. § 20101), 1958. https://uscode.house.gov/view.xhtml?path=%2Fprelim%40title51&req=granuleid%3AUSC-prelim-title51&f=&fq=&num=0&hl=false&edition=prelim

[2] National Institute of Aerospace, 2011 NASA RASC-AL Themes, 2010, August. http://rascal.nianet.org/wp-content/uploads/2015/07/2011_RASC_AL-THEMES.pdf

[3] Executive Office of the President, Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, 2017, 11 December. https://www.whitehouse.gov/presidential-actions/presidential-memorandum-reinvigorating-americas-human-space-exploration-program/

[4] National Institute of Aerospace, 2018 NASA RASC-AL Themes, 2017, August. http://rascal.nianet.org/wp-content/uploads/2017/08/2018-RASCAL-Themes-Flyer.pdf

[5] National Institute of Aerospace, 2020 NASA RASC-AL Themes, 2019, August. http://rascal.nianet.org/wp-content/uploads/2018/08/2019-RASC-AL-Themes.png

[6] National Aeronautics and Space Administration, Strategic Plan 2018. https://www.nasa.gov/sites/default/files/atoms/files/nasa_2018_strategic_plan.pdf

[7] National Institute of Aerospace, Annual Report, 2018. https://www.nianet.org/wp-content/uploads/2019/09/2018-NIA-Annual-Report.pdf

[8] National Institute of Aerospace, RASC-AL website, 2019. http://rascal.nianet.org/

[9] Paragon TEC, NASA STEM Engagement Higher Education Challenges, Competitions, and Internships Multiple Case Study, 2019 June 14.

[10] University of Puerto Rico-Mayaguez, Lunar Exploration and Access to Polar Regions (LEAPR) RASC-AL 2019 Technical Report, 2019 May 30.

[11] Colorado School of Mines, Project POSEIDON: Polar Sample Extraction In-Situ Drilling Operations Network Technical Report, 2018, May 31.

[12] University of Maryland College Park, RASC-AL Technical Paper: Ultima Thule, 2017, May 15.


## Vitae

**Carol Galica** is a Systems Engineer for Stellar Solutions Inc. and senior advisor for the NASA Lunar Surface Innovation Initiative within the Space Technology Mission Directorate at NASA headquarters. Carol is working to spur the creation of novel technologies needed for lunar surface exploration and accelerate the technology readiness of key systems and components. She previous served as the technical advisor for university engagement and partnerships to the Human Exploration and Operations Mission Directorate Advanced Exploration Systems division and provided technical expertise to support the utilization of educational and public entities to provide technical risk reduction related to the challenges of human spaceflight. She developed strategic partnerships and collaborations with universities, high schools, nonprofit organizations, and the public to bridge gaps in technology for human spaceflight through risk reduction.

**John Guidi** is a deputy director of the Advanced Exploration Systems Division with NASA's Human Exploration and Operations Mission Directorate. John joined NASA in 1987 at Kennedy Space Center serving various positions within Space Shuttle Operations, including Shuttle test director, Launch Manager, and Shuttle Launch and Landing Division Chief He moved to NASA headquarters/DC in 2005 as Operations project manager for the newly formulated Constellation Program and later as Ground & Mission Ops Program Executive. From February 2007 to February 2011, John served as deputy director, ESMD Directorate Integration Office which provided integrated technical and management planning across ESMD and later joined HEOMD/Advanced Exploration Systems Division as deputy director in 2011 leading international partnerships, science integration and human spaceflight architecture strategic planning and analysis.

**Patrick A. Troutman** serves as the lead for human exploration strategic assessments at the NASA Langley Research Center where his current efforts include developing what the next set of activities for humans should be beyond the international space station, and how those missions will prepare humanity for missions to the Moon and Mars. In the past 30 plus years he has worked for NASA designing and assessing the International Space Station, leading systems analysis related to future space scenarios including managing the NASA Revolutionary Aerospace Systems Concepts (RASC) program, helping to define the Vision for Space Exploration, leading the integration for the Constellation Program lunar surface architecture, and leading human space exploration mission design for the

NASA Human Spaceflight Architecture Team and the Evolvable Mars Campaign.

**Shelley Spears** is the Director of Education and Outreach at the National Institute of Aerospace. Shelley has responsibility for outreach development, program management, strategic initiatives, and management of a high performance team of experienced professionals. She leads a variety of STEM educational outreach projects including: Virginia 21eTeacher Initiative, NASA Langley Research Student Scholars (LARSS), NASA's oldest and largest college intern program; NASA Revolutionary Aerospace Systems Concepts - Academic Linkages (RASC-AL and RASC-AL Robo--Ops); NASA eClips™, an award winning multimedia program for K12 students and teachers; NASA y Tu, NASA's first multi-media bilingual K-12 program; RealWorld-InWorld Engineering Design Challenge, a design competition for secondary and college students utilizing virtual world technology; and Virginia's Residential Governors School for. Shelley has over 14 years' experience in developing and executing STEM educational outreach programs.

**Stacy Dees** serves as NIA's Outreach project manager, administering university-level engineering design competitions for NASA. Previous roles have included Acting Director of NASA's Langley Aerospace Research Summer Scholars (LARSS) Program, and program manager for the NASA MAES Undergraduate Scholarship Program with the Society of Mexican American Engineers and Scientists (MAES). Stacy received the President's Award from SHPE, and a NASA Group Achievement Award for the administration of the LARSS program. Combined with her training in project management and working for academia, federal, and nonprofit organizations in a variety of roles, Mrs. Dees is equipped with a unique ability to successfully manage all aspects of large-scale projects. She has over 15 years of experience managing federal education programs, spending a significant amount of that time administering minority-focused education programs for NASA.