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Building on 50 Years of Mission Operations Experience for a New Era of Space Exploration

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Abstract

The U.S. National Space Policy,[1] the 14-nation Global Exploration Strategy,[2] and the National Aeronautics and Space Administration's (NASA) 2006 Strategic Plan[3] provide foundational direction for far-ranging missions, from safely flying the Space Shuttle and completing construction of the International Space Station by 2010, to fielding a next generation space transportation system consisting of the Ares I Crew Launch Vehicle/Orion Crew Exploration Vehicle and the Ares V Cargo Launch Vehicle/Altair Lunar Lander (fig. 1). Transportation beyond low-Earth orbit will open the frontier for a lunar outpost, where astronauts will harness *in-situ* resources while exploring this 4 billion-year-old archaeological site, which may hold answers to how the Earth and its satellite were formed. Ultimately, this experience will pave the way for the first human footprint on Mars.

Fig. 1. NASA concept of the Ares I/Orion (right) and the Ares V.

In October 2007, NASA announced assignments for this lunar exploration work.[4] The Marshall Space Flight Center is responsible for designing, developing, testing, and evaluating the Ares I and Ares V, which are Space Shuttle derived launch vehicles, along with a number of lunar tasks. The Marshall Center's Engineering Directorate provides the skilled workforce and unique manufacturing, testing, and operational infrastructure needed to deliver space transportation solutions that meet the requirements stated in the Constellation Architecture Requirements Document (CARD). While defining design reference missions to the Station and the Moon, the CARD includes goals that include reducing recurring and nonrecurring costs, while increasing safety and reliability. For this reason, future systems are being designed with operability considerations and lifecycle expenses as independent variables in engineering trade studies.

Within Marshall's Engineering Directorate, the Mission Operations Laboratory team has been integral to NASA's missions from the earliest days of U.S. spaceflight to current International Space Station science operations. This paper will give a brief history relative to NASA's 50th anniversary and provide top-level information about involvement in current Shuttle and Station missions, as well as the design and development work in progress for a number of exploration-related initiatives. For example, the Ares I Operational Concepts Document has been developed by Mission Operations personnel in partnership with the Mission Operations Directorate at the Johnson Space Center and the launch services provider at the Kennedy Space Center to address such challenges as developing ground support equipment, documenting work flow, reducing the logistics footprint, and adopting streamlined concepts such as those followed for expendable launch vehicles. Creating appropriate handoffs from development engineering to operations functions is one of many decisions to be made relative to fielding a new space transportation system.

When performing analytical studies to improve the turnaround time for the new system, technical metrics are balanced with programmatic cost and schedule targets. One outcome has been the decision to mate the J-2X engine in the upper stage prior to shipping to the launch site. Another innovation has been to develop a full-scale mockup of the Ares I upper stage instrument unit ring, which provides guidance and control and other avionics functions to the craft, and the interstage structure, complete with low-fidelity engine mold line. This serves as physical mockup for laying out components and testing ground support equipment concepts, translating them from two-dimensional computer aided modeling and simulation to three-dimensional structures. This simulator is being used by design engineers and operators to make decisions that ultimately will affect the lifecycle costs of the Ares I.

Fig 2. The Ares I instrument unit/interstage simulator is located at Marshall's Propulsion Research Development Laboratory.

With over 6 years of experience working with international crews on the Space Station and corresponding scientists on Earth, the Mission Operations Lab has the talent, facilities, protocols, and distributed network in place to conduct operations 24 hours a day/7 days a week in the Payload Operations Center (fig. 3). This capability builds on decades of experience monitoring Shuttle propulsion elements during launch and working with crewmembers to conduct real-time hands-on Skylab and Spacelab microgravity science missions. Services include procedures and timeline development along with crew training, as well as coordinating payload activities for the Station's international partners, including the Russian Space Agency, European Space Agency, National Space Development Agency of Japan, and Canadian Space Agency.[5] Planning for future missions beyond low-Earth orbit, Marshall's Mission Operations works closely with the Mission Operations Directorate and with Launch Operations to find innovative ways to reduce the new space transportation system's operational footprint across the board by building on the knowledge, experience, infrastructure, and resources resident in each, while providing the integration for international scientific cooperation. Through this approach, NASA and its industry partners are addressing and identifying long-term solutions for sustainable space exploration.

Fig. 3. Marshall's Mission Operations Laboratory monitors Shuttle propulsion elements during launch and provides scientific support for Station science operations.

References

1. U.S. National Space Policy, Office of Science and Technology Policy, ADD DATE, www.ostp.gov/html/US%20National%20Space%20Policy.pdf

2. Global Exploration Strategy, December 2007, www.nasa.gov/home/hqnews/2007/may/HQ_07126_Exploration_Framework.html

3. NASA 2006 Strategic Plan, www.nasa.gov/audience/forpolicymakers/index.html

4. Exploration Systems Mission Directorate Work Assignments, October 30, 2007, www.nasa.gov/mission_pages/constellation/main/constellation_workforce.html

5. Payload Operations Center Fact Sheet, March 2001, http://www.nasa.gov/centers/marshall/news/background/facts/POC.html

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Abstract

The U.S. National Space Policy, the 14-nation Global Exploration Strategy, and the National Aeronautics and Space Administration's (NASA) 2006 Strategic Plan provide foundational direction for far-ranging missions, from safely flying the Space Shuttle and completing construction of the International Space Station by 2010, to fielding a next generation space transportation system consisting of the Ares I crew launch vehicle/Orion crew exploration vehicle and the Ares V cargo launch vehicle/Altair lunar lander, along with lunar surface systems and mission and ground operations. Transportation beyond low-Earth orbit will open the frontier for a lunar outpost, where astronauts will harness *in-situ* resources while exploring this 4 billion-year-old archaeological site, which may hold answers to how the Earth and its natural satellite were formed. Ultimately, this experience will pave the way for the first human footprint on Mars. Within the Marshall Space Flight Center's Engineering Directorate, the Mission Operations Laboratory team has been integral to NASA's missions from the earliest days of U.S. spaceflight to current International Space Station science operations, delivering high-bandwidth data to both domestic and international partners. This paper gives a brief history of the Mission Operations Laboratory relative to NASA's 50th anniversary and provides top-level information about the organization's involvement in current Shuttle and Station missions, as well as the design and development work in progress for a number of exploration-related initiatives. For example, the Ares I Operational Concepts Document has been developed by Mission Operations Lab personnel in partnership with the Constellation Program's Mission Operations Project at the Johnson Space Center and the Ground Operations Project at the Kennedy Space Center to address such challenges as transitioning workforce, revamping infrastructure, developing ground support equipment, reducing the logistics footprint, and adopting streamlined concepts such as those followed for expendable launch vehicles. Creating appropriate handoffs from development engineering to operations functions is one of many decisions to be made relative to fielding a new space transportation system. The Mission Operations Lab has the specialized facilities, experienced personnel, and solid relationships with domestic and international partners — all contributing factors for ushering in a new era of scientific exploration from the unique vantage point of space.

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I. Background: The Operations Case for Sustainable Exploration Solutions

Following the recommendations made by the Exploration Systems Architecture Study in 2005,[1] NASA has been engaged for the past 3 years in designing the Ares I/Orion system and completing preliminary designs for the Ares V/Altair. With this measurable progress, it has put in place the technical and business foundation needed to regain America's ability for humans to travel beyond Earth orbit for renewed lunar exploration as a precursor to longer missions to Mars, one of Earth's closest planetary neighbors. The recently completed Lunar Capability Concept review[2] reiterated the Agency's plan to team with international partners for surface systems and science missions to be conducted on the Moon.

Reflecting a balanced portfolio of robotic and human exploration, NASA's Lunar Reconnaissance Orbiter and Lunar Crater Observation and Sensing Satellite (LCROSS) are set for a late 2008 mission on an Atlas V launch vehicle. LCROSS will help scientists search for water ice in a permanently shadowed crater in the Moon's polar region.[3] Analysis of recent data returned from the Mars Phoenix mission shows that the materials needed to support life are present on the red planet, including water in ice form.[4] The implication of these missions, among others, foreshadows the inevitable expanded human habitation of the Moon and Mars.

As shown in the schedule below (fig. 1), the exploration strategy encompasses several decades and includes significant milestones such as retiring the Space Shuttle, which has served with distinction for almost 30 years, as well as fielding the Ares I in the 2015 timeframe and the Ares V cargo vehicle around 2020 (fig. 2).

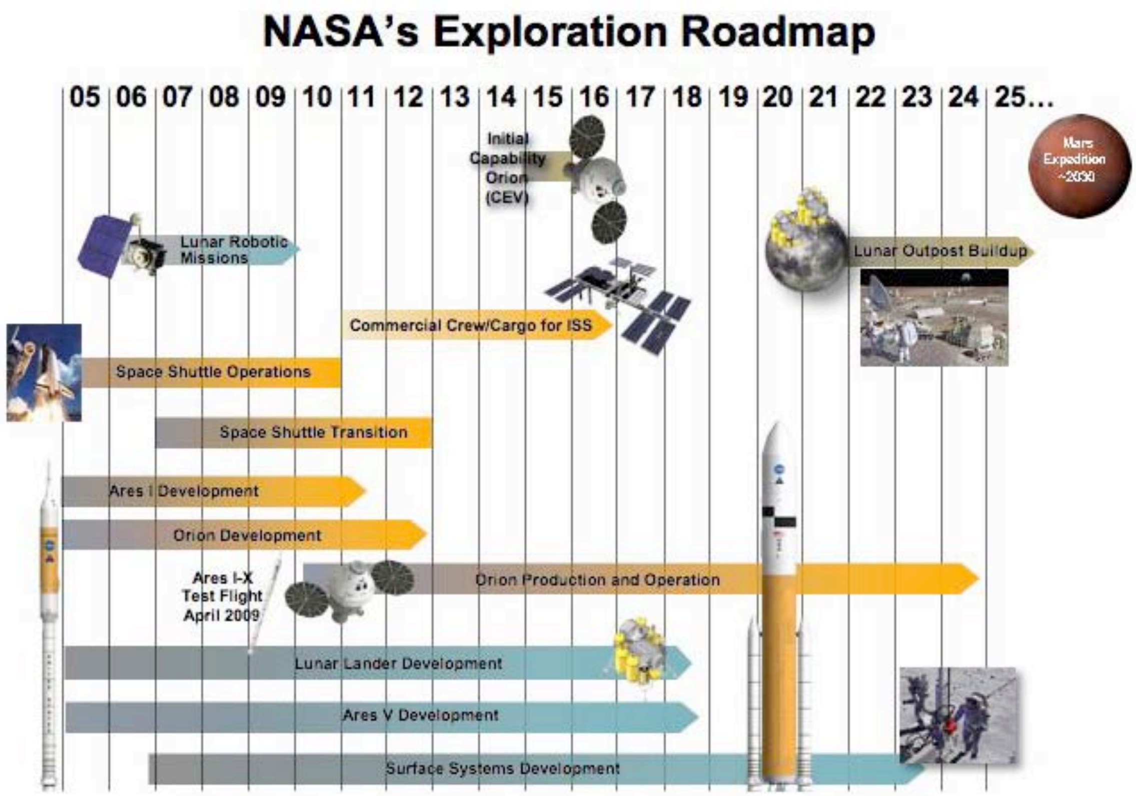

Fig. 1. NASA's exploration strategy is a multi-decade endeavor.

Throughout this period of building integrated master schedules and interlinked budgets that reflect the Agency's fiscal accountability, selecting industry partners through competitive procurements, and performing exacting engineering design and analysis, the Ares I and Orion projects have completed several systems engineering reviews and are moving from the design phase into hardware development. NASA is dedicated to delivering exploration solutions based on requirements for safety, robustness, and streamlined supportability to reduce operations costs, allowing the Agency to focus its finite resources on mission objectives, rather than on infrastructure expenses. The forthcoming architecture will be a national asset that will promote the peaceful pursuit of space science for generations to come in a sustainable manner (fig. 3).

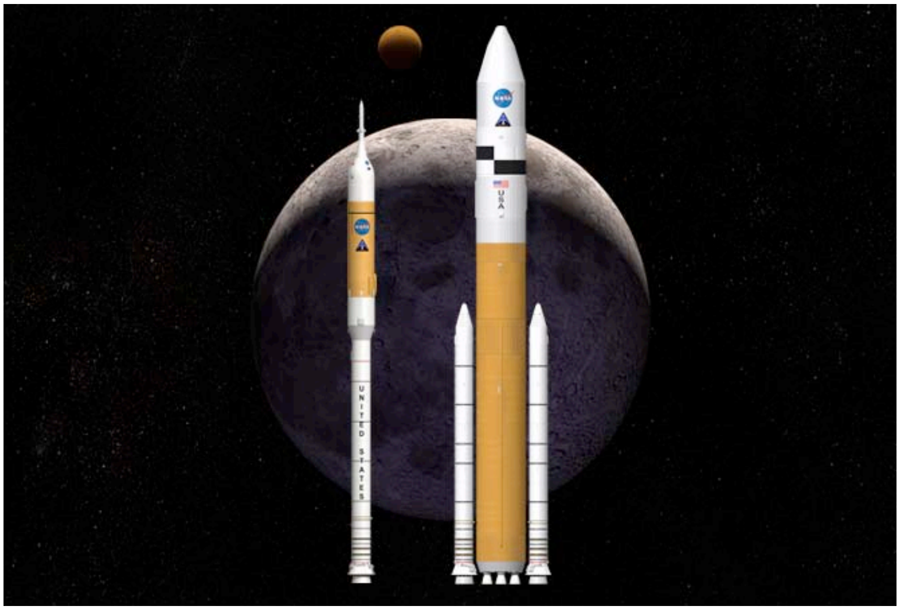

Fig. 2. NASA concept of the Ares I/Orion (left) and the Ares V.

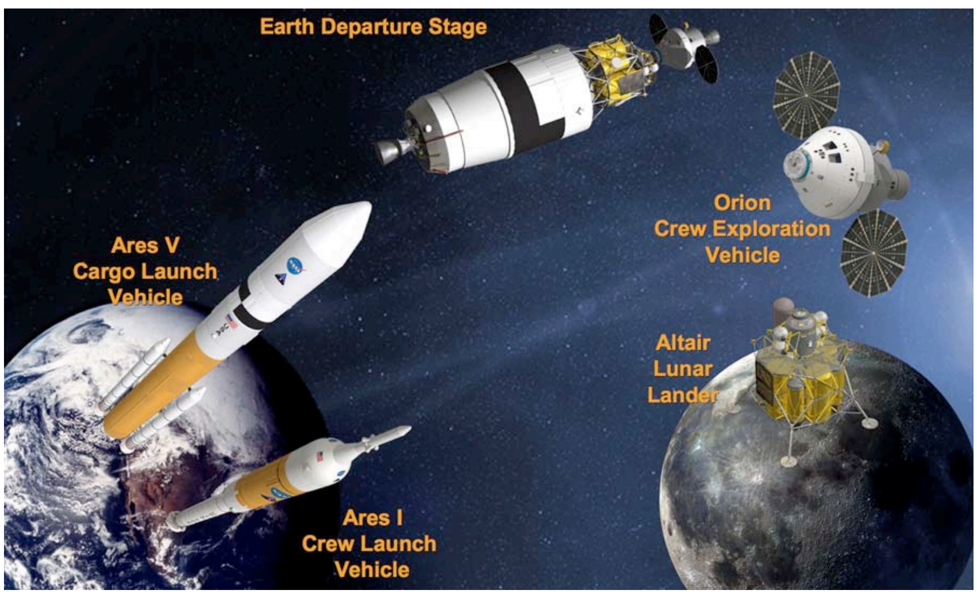

Fig. 3. NASA's Constellation Program manages the exploration architecture.

Guiding this effort are principles outlined in the U.S. National Space Policy, the 14-nation Global Exploration Strategy, and the NASA 2006 Strategic Plan.[5,6,7] In October 2007, NASA announced assignments for this lunar exploration work.[8] The Marshall Center is responsible for designing, developing, testing, and evaluating the Ares I and Ares V, which are Shuttle derived launch vehicles, along with a number of lunar tasks. Marshall's Engineering Directorate provides the skilled workforce and unique manufacturing, testing, and operational infrastructure needed to deliver space transportation solutions that meet the requirements stated in the Constellation Architecture Requirements Document (CARD). While defining design reference missions to the International Space Station and the Moon, the CARD includes goals that include substantially reducing recurring and nonrecurring costs, while increasing safety and reliability. In keeping with this philosophy, future systems are being designed with operability considerations and lifecycle expenses as independent variables in engineering trade studies.

When performing analytical studies to improve the turnaround time for the new system, technical metrics are balanced with programmatic cost and schedule targets. For example, one outcome has been the decision to mate and test the J-2X upper stage engine in the upper stage structure prior to shipping, reducing the need to close open-work items at the launch site. Another innovation has been to develop a full-scale mockup of the Ares I upper stage instrument unit ring, which provides guidance and control and other avionics functions to the craft, and the interstage structure, complete with low-fidelity engine mold line (fig. 4). This serves as a physical mockup for laying out components and testing ground support equipment concepts, translating them from two-dimensional computer aided modeling and simulation to three-dimensional structures. Design engineers and operators use this simulator to make decisions that ultimately will affect the lifecycle costs of the Ares I.

Fig 4. The Ares I instrument unit/interstage simulator is located at Marshall's Propulsion Research Development Laboratory.

This is just one of many examples of how the Ares team, which is composed primarily of Engineering Directorate employees, is designing the new space transportation system for operability over its projected 30-year lifetime. This imperative will promote the ability to conduct round-the-clock science missions off planet, in much the same way as Station operations are conducted today.

Given below is a background summary of the Engineering Directorate's Mission Operations Laboratory and how its capabilities are in place to support long-term space science missions, as well as a top-level overview of the Ares I operational concept document it has produced in keeping with the mandate to make launch operations more streamlined and efficient, while utilizing current capabilities to the fullest extent possible.

II. The Mission Operations Laboratory's Legacy of Success

While the Marshall Center is best known for its engineering achievements, such as developing the Saturn V Moon rocket, it also is steeped in almost 50 years of scientific successes through a range of programs such as Skylab — America's first space station — and Spacelab, which used the microgravity environment of the Space Shuttle in free-fall around Earth to unmask gravity's effects on fundamental biological and physical processes and its open payload bay for astronomical observations above Earth's atmosphere. Today, the Mission Operations Lab is the command post for science on the Space Station. This section gives a brief history of Marshall's Mission Operations Lab and how its facilities and team have contributed to NASA's scientific missions over the last 5 decades.

The roots of this exceptional operational capability flourished from of the launch of America's first satellites in 1958 at the dawn of the Space Age. The Army Ballistic Missile Agency (ABMA) was responsible for seven successful missions using Juno launch vehicles. The ABMA formed the basis for today's civil space agency, chartered in 1958, and NASA's Marshall Space Flight Center, which became a tenant organization on Redstone in 1960.

The ABMA operated a network of tracking stations for Juno upper stages and Explorer satellites, with data transmitted by teletype, plotted by hand, and key-punched into IBM 704 computer cards. With its background providing real-time support activities for Juno launches and post-flight data reduction and flight evaluation, the Huntsville Operations Support Center (HOSC), which is a primary constituent of the Mission Operations Lab, was transferred from the Army to NASA in the 1960s to provide Saturn/Apollo real-time engineering support during key pre-launch and flight activities, linking the primitive communication networks of the day between Marshall and the Johnson Space Center's Mission Control Center and the Kennedy Space Center's Launch Control Complex (fig. 5).

Fig. 5. Saturn flight control room, circa 1966.

From the Juno/Explorer era in 1958 to 1962, and during the Saturn/Apollo era in 1960 to 1975, the HOSC information capabilities grew exponentially to provide the latest information networks and perform critical data analyses for the Shuttle era from 1975 to the present. As these resources have evolved over time, the data system for Saturn was transformed from voice/teletype communications and hand plotting to the once state-of-the-art 59 kilobits per second (kbs) circuit from Kennedy and a 9.6 kbs circuit from Johnson. Console displays used strip chart recorders, analog meters, event lights, and digital-to-television conversion. Computations were initially performed on a Burroughs B550 computer and, later, on Univac 1100 mainframes — brand names that have now disappeared into history books.[9]

During the Skylab missions in the 1970s, science operations were performed 24 hours a day/7 days a week for 9 months, foreshadowing this unique facility's role in Shuttle Spacelab missions, which lasted from 6 to 24 days, and present-day science operations conducted full-time aboard the Station. During the Shuttle's almost 3 decades of operation, Marshall's personnel have supported the Shuttle propulsion elements, which are managed by Marshall, along with multiple scientific projects, including the Hubble Space Telescope, Chandra X-Ray Observatory, and the multitude of scientific payloads flown either in the Spacelab's shirt-sleeve laboratory module or on its exposed platform in the Shuttle's payload bay.

Spacelab was developed by the European Space Agency (ESA), under an agreement with NASA. This reusable laboratory brought together domestic and international scientists from around the world, many who converged at the HOSC's Payload Operations Control Center, where command and data management subsystems and high-data-rate multiplexers and recorders were located, to observe and interact with experiments conducted by crews who had trained at Marshall's Payload Crew Training Complex. The Spacelab Mission Planning System was a pathfinder in automating mission analysis and optimizing timelines — where every minute and resource count — and is the foundation for science planning capabilities employed today for Station payloads.

Shuttle vehicle development activities performed at Marshall included trajectory planning and propulsion performance prediction. Today, Shuttle launch support includes analysis of propellant loading, countdown, launch, and powered flight toward orbit. From the HOSC, Marshall personnel monitor the status of propulsion systems and receive data from sensors aboard the Shuttle through a sophisticated communications network. Post-flight data analysis is used to predict performance for future flights (fig. 6).

Fig. 6. Shuttle data reduction.

As shown in Table 1, the Mission Operations Lab has been a creative and resourceful partner throughout NASA's 50 years of human and robotic exploration of Earth, its planetary solar system, and the infinite cosmos beyond the Milky Way. From engineering, to mission analysis, to the information systems that form the backbone of scientific study, this capability is critical to expanding Station science operations now that its core structure is complete and the U.S. Destiny lab, the European Columbus lab (fig. 7), and the Japanese Kibo lab have been installed and activated. These pivotal activities foreshadow the nation's return to the Moon in the 2020 timeframe, where science aboard the Station will contribute to methods that keep crews healthy and productive during long-duration space flight, as well as promote materials and systems for lunar astronauts. Lunar science will be the next giant leap in promoting America's pioneering spirit.

Table 1. Mission Operations Lab's contributions to NASA's 50 years of space flight.

Program Era	Projects	Mission Operations Functions											
			Mission Analysis			Mission Support				Information Systems			
		Engineering Support	Flight mechanics	Orbital Mechanics	Operations Timeline	Flight Control	Science Operations	Crew Support and Training	Training Simulations	Inter-Center Data Requirements	Data Reduction	Real-Time Data Processing	Command Processing
Juno/ Explorer 1958–1962	Juno Launch Vehicles		•								•	•	
	Explorer Satellites			•							•	•	
Saturn/ Apollo 1960–1975	Saturn launch Vehicles	•	•	•	•	•				•	•	•	
	Lunar Rover	•								•		•	
	Skylab	•	•					•		•	•	•	
Space Shuttle 1975–Present	Space Shuttle	•	•							•	•	•	
	Shuttle Payloads/Spacelab	•		•	•		•	•	•	•	•	•	•
	Intertial Upper Stage	•	•		•					•	•	•	
	International Space Station	•		•	•	•	•	•	•	•	•	•	•
	HEAO Free-Flyers	•		•	•	•	•		•	•	•		
	Hubble Space Telescope	•		•	•			•	•	•	•	•	
	Chandra Observatory	•		•	•	•		•	•	•	•	•	•

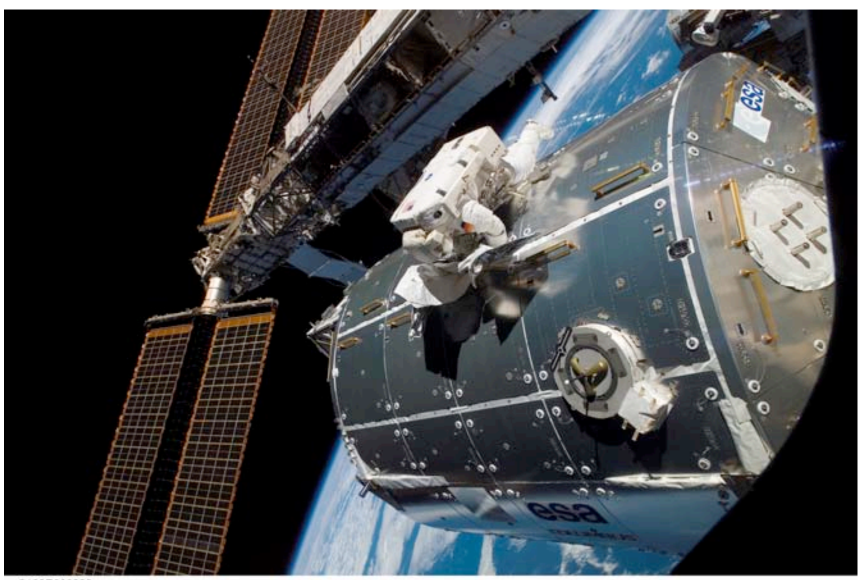

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Fig. 7. Europe's Columbus Laboratory was delivered to the Station in 2007 by the Space Shuttle.

III. International Space Station Science Operations: A Foundation for Future Exploration

The present-day HOSC is a one-of-a-kind infrastructure asset with broad capabilities and experience (fig. 8). Station operations began in 1998, supported by multiple Shuttle launches. Payload operations are integrated through the Payload Operations Integration Center within the HOSC. Control of individual experiments is distributed to international partner and user sites, in an extension of the Spacelab model. For the Space Station, the enhanced HOSC system (EHS) is based on a modified version of that developed my Marshall and employed by the Chandra Operations Control Center at the Smithsonian Astrophysical Observatory. The PC-based EHS enables control of experimental operations from locations that are remote from the HOSC. The telescience resource kit allows users to access EHS capabilities from locations across the globe.

Fig. 8. The Mission Operations Lab's Huntsville Operations Support Center.

The Payload Operations Center (fig. 9) manages all NASA science research experiment operations aboard the Station.[11] It also coordinates mission-planning work of a variety of international sources, all NASA science payload deliveries and retrieval, and NASA payload training and payload safety programs for the Station crew and all ground personnel. With this technical foundation and skill set, services include procedures and timeline development along with crew training, as well as coordinating payload activities for the Station's international partners and scientists (fig. 10), including the Russian Space Agency, European Space Agency, National Space Development Agency of Japan, and Canadian Space Agency.[12]

Fig 9. The Payload Operations Center performs 24 hours a day year round.

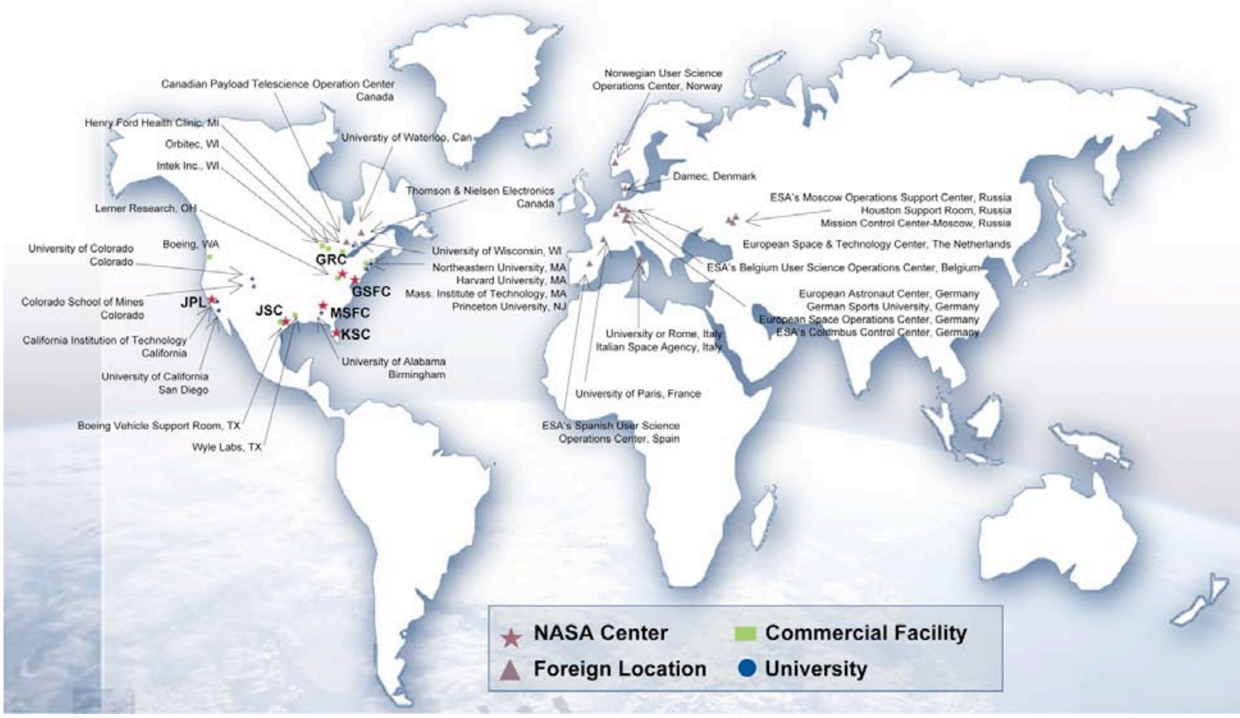

Fig. 10. The Mission Operations Lab supports and connects remote sites worldwide.

The Mission Operations cadre has supported Station science non-stop since March 2001, when the U.S. Destiny module was installed and crews began inhabiting the orbital outpost full time. Throughout the life of the Station, the Payload Operations Center will integrate research requirements, plan its science missions, and ensure that they are safely executed. It will integrate crew and ground team training and research mission timelines. It also will manage use of Station payload resources, handle science communications with the crew, and manage commanding and data transmissions to and from the orbiting research center, which is a technological and physiological test-bed for long-duration missions such as journeys to Mars. Staffed around the clock by three shifts of flight controllers, table 2 provides a frame of reference for some of the responsibilities and duties entrusted to this cadre.

Table 2. Payload Operations Center cadre functional responsibilities.

Title	Responsibilities
Payload Operations Director	• Manages daily operations of Station payloads. • Single point of authority to the Station's Mission Control Center Flight Director. • Oversees team members responsible for managing payload mission planning, ground commanding of space station payloads, communications with the crew, use of the payload support system, the video system and the data systems. • Ensures compliance with established safety requirements, flight rules and payload regulations. • Leads the review and approval of all change requests to the timeline.
Operations Controller	• Leads a team that is responsible for maintaining the daily payload work assignments, ensuring scheduled research activities are accomplished safely and on time, and managing and tracking available resources. • Leads resolution of NASA payload anomalies and monitors troubleshooting of on board systems to identify possible impacts to payload operations. • Assesses change requests for impacts to the current science timeline, payload hardware assets and resources required for science such as crew time and electrical power. • Evaluates scientist request for experiment timeline changes, and then implements changes to the science operations plan.

Table 2. Payload Operations Center cadre functional responsibilities (continued).

Title	Responsibilities
Lead Increment Science Representative	• Provides research priorities to the Payload Operations Center cadre for its planning and implementation of the science mission. • Works with the Lead Increment Scientist, payload mission integration teams, remote research teams and other users. • Tracks payload status and accomplishments, and manages research-related issues.
Payload Rack Officer	• Responsible for configuring ExPRESS payload racks in the U.S. Destiny laboratory, and for coordinating the configuration of systems resources to all NASA payload racks. • Configures new payload rack interfaces to properly support the payload. • Monitors the health and status of both the payload and the rack and if necessary, coordinates troubleshooting of the payload support structure and payload interfaces. Responsible for managing all ground commanding of U. S. payload systems and experiments. Manages the command link, receives and sends command files to the mass storage device, and configures the system to allow flight controllers in the Payload Operations Center and remote users to send commands to their equipment.
Data Manager Coordinator	• Responsible for command, control, data handling, communications and tracking for science payloads on the space station. • Manages the integrated high data rate (Ku-band) communications link between the ground and the station. • Manages data system traffic, downlink video, assures ground data quality with NASA users, and assesses data system change requests. • Ensures that the data system is properly configured to support payload operations. • Responsible for managing video coverage of research activity on the Station. • Monitors, configures and coordinates the use of the video system.
Payload Communications Manager	• Using the call sign, "Huntsville," is the prime communicator with the astronaut crew on payload matters. • Responsible for enabling global researchers to talk directly with the crew about their experiments and for managing payload conferences. • Reviews requests for changes to payload activity to assess impact on the crew.
Shuttle Operations Controller	• Responsible for all science payloads while they are on board the Shuttle for transport to the Station. • Tracks the payloads activities, and manages changes to the Shuttle flight plan based upon the payload user requirements. • Coordinates the transfer activities of the payload, payload packing for return, and ensures that no science is lost during the transfer to and from the Station. • Serves as the interface between the Payload Operations Center and shuttle Mission Control Center during Shuttle flights.

The list above shows only a few of the hundreds of people engaged in Shuttle, Station, and Ares launch vehicles work. For example, Marshall also develops flight hardware for the Station, such as the science racks that help integrate multiple payloads in a standardized, modular, and streamlined approach, along with the Oxygen Generation System and Water Recovery Systems as part of the Station's Environmental Control and Life Support System (ECLSS) that has enabled its permanent crew to grow to 3 astronauts in early 2008 and up to 6 in 2009 with the delivery of additional ECLSS equipment in late 2008.[13] Station structures developed and managed by Marshall include the Station's connecting nodes, which provide internal storage space and hold life support equipment.

Many experiments conducted on the Station are focused on life sciences and designed to help develop technologies and materials for future spacecraft and exploration missions. For instance, Marshall developed the Lab-on-a-Chip handheld device for rapid detection of biological and chemical substances, which was successfully tested by astronaut Sunita Williams as part of the Expedition 14 team.[14] In these and many other ways, the Payload Operations Center is, in essence, a test-bed for operational concepts that will pay dividends during missions to come.

IV. Planning the Ares I Operations Concept

The Mission Operations Lab performs operations concept development, analyzes and develops mission operations requirements for flight and ground systems, plans and prepares for mission operations, implements mission support systems, and conducts ground and flight operations. Broad responsibilities include:

- Supporting and implementing the planning, budgeting, scheduling, engineering design, development, testing, and cost control of assigned mission operations functions.
- Planning and conducting assigned missions.
- Developing, managing, and operating mission ground systems that provide command and control, mission planning services, and data analysis support for flight systems and payloads.
- Providing operations integration for future space flight projects associated with immediate and long-range objectives and goals.

Today's launch operations are complex, time-consuming, and require a great deal of hands-on labor. When the Ares I begins its operational phase in the 2015 timeframe, it will be the culmination of a detailed process that involves launch vehicle design engineers working in tandem with their operations counterparts to ensure that the system delivered meets requirements, goals, and objectives. Planning for future missions beyond Earth orbit, Mission Operations Lab personnel work closely with the Constellation Program's Mission Operations Project and Ground Operations Project to find innovative ways to reduce the new space transportation system's operational footprint across the board by building on the knowledge, experience, infrastructure, and resources of NASA and its industry partners, while serving as the integration point for international scientific cooperation. Through this approach, NASA and its partners in the U.S. aerospace community and countries abroad are identifying and addressing long-term solutions for sustainable space exploration, with mutually beneficial goals and objectives.

The Ares I Operational Concepts Document has been developed by Mission Operations personnel in partnership with Mission Operations and Ground Operations to streamline processes for quicker vehicle turnaround and simpler interfaces for less "touch" labor. The launch vehicle design drives modifications to the Vehicle Assembly Building and Launch Complexes at Kennedy (fig. 11), as well as requirements for ground support equipment, work flow, and reducing the overall logistics footprint from manufacturing, to shipping, to stacking and launching. Considering these objectives early in the design process is a risk-mitigation strategy for building in cost-efficiencies for the operations phase.

Fig. 11. NASA concept of the Ares I launch pad, with lightning tower that also will serve the Ares V.

The Operations Concept addresses specific Ares I goals, including:

- Achieve a significant reduction in operations cost from legacy systems, with the goal to operate at a steady-state flight rate of 5 flights per year.
- Simplify and minimize ground processing and integration operations such that the system can be launched within 45 calendar days from start of assembly.
- Effectively size the system to support various mission types (Space Station, lunar sortie, etc.) and number of missions in any given year; support up to 6 (5 plus surge) flights per year.
- Be interchangeable with either mission type (crew or cargo) such that no significant changes in processing flow or element hardware are required.
- Achieve the appropriate balance between the use of line replaceable units, reliable component selection, and maintenance operations to support a launch availability of not less than 98 percent (not including natural environmental impacts).
- Reduce launch pad maintenance during the 4-day launch window.
- Be capable of a 24-hour turnaround following a launch scrub.
- Use common, reusable ground support equipment.
- Incorporate common parts and tooling as much as practical.
- Be capable of remaining in a stacked configuration for up to 180 days.
- Minimize ground system diagnostic, maintenance, and umbilical interfaces.
- Implement a logistics support concept with the appropriate balance between just-in-time shipment, certification life, and hardware spares to minimize the launch site logistics footprint (storage facilities, equipment, and personnel) and to eliminate the need for on-site hardware recertification.

Ares I ground and flight operations concepts and goals are driven by the mission manifest; Design Reference Missions (DRMs); Constellation Program goals, objectives, and constraints; and Ares I design decisions. Operations goals are established as a target for improving upon existing capabilities. Operations requirements are based on operations analyses and timelines (such as turnaround time, launch availability, and so forth) using the mission manifest, DRMs, and Program inputs, including management margin. Analysis results are compared to the operations goals, and programmatic decisions will be made to establish the final requirements.

V. Conclusion: The Next Giant Leap in Space Exploration

In June 2008, NASA engineers and scientists completed a Lunar Capability Concept (LCC) review to determine the systems capabilities necessary in order to return humans to the Moon and establish an outpost (fig. 12). This milestone completes a 9-month study by the Exploration Systems Mission Directorate, which took into consideration the objectives developed by the Global Exploration Strategy. The study looked at possible lunar mission scenarios and compared them to the projected capabilities of the emerging Ares V heavy lift launch vehicle and the Altair lander design concepts, which are key components of the greater exploration architecture. Led by the Constellation Program, the LCC established the technical parameters needed to begin preparing Ares V and Altair vehicle requirements. One outcome of this study was to confirm the overarching need for international partnerships to deliver on the long-term exploration strategy. The stage is set for expanding the network of countries that will be involved in this endeavor, which ultimately will benefit all Earth's citizens.

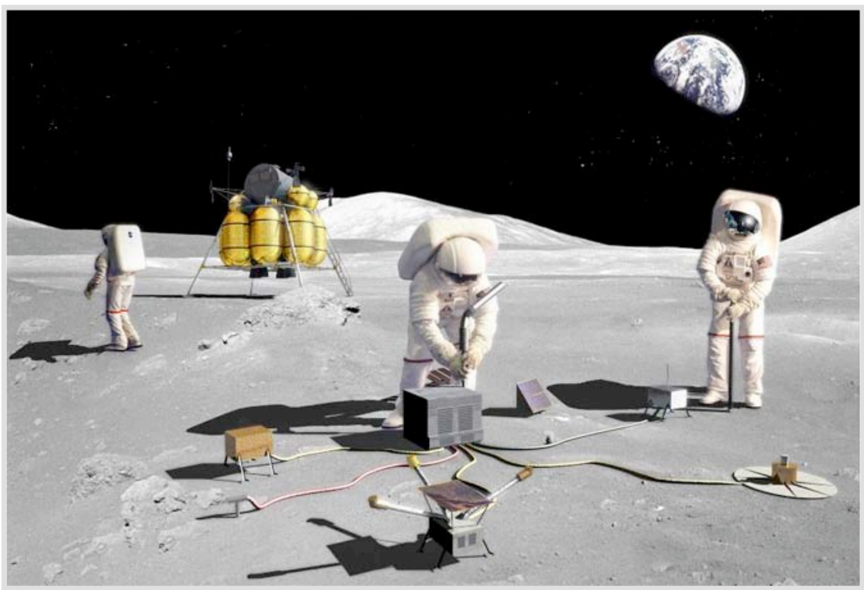

Fig. 12. NASA lunar mission concept.

In keeping with the principles of the Global Exploration Strategy — a framework for coordinating space exploration plans of 14 participating agencies from around the world — NASA is pursuing its lunar exploration plans under an "open architecture" approach to foster international and commercial collaboration. In April 2008, Europe's Jules Verne Automated Transfer Vehicle was launched and docked with the Space Station, expanding cargo delivery and reboost capabilities for the orbital complex.[15] In July 2008, NASA released the results of a joint study with the European Space Agency in a detailed assessment of how its member nations can participate to the fullest in human space exploration, building on their extensive experience from Spacelab and the Station. Some of the concept scenarios assessed included potential future use of an automated Ariane V-based lunar cargo landing system; European developed communication and navigation systems; and ESA-developed human-rated systems and orbital structures.[16]

These preliminary planning activities underscore the benefits that the Marshall Center's Mission Operations Laboratory offers for the next giant leap in the scientific exploration of space. The organization encompasses the talent, facilities, protocols, and distributed data connections to conduct uninterrupted operations 24 hours a day/7 days a week. This asset builds on decades of experience collaborating with domestic and international principal investigators and crewmembers to conduct real-time space-based experiments. With a sound experience base, cutting-edge information technology networks, and well-established relationships with U.S. and foreign partners, the Mission Operations Laboratory offers a seamless way to take space exploration to the next level — from low-Earth orbit to the Moon, Mars, and beyond.

References

1. *Exploration Systems Architecture Study*, Final Report, Technical Manual 2005-214062, November 2005, www.sti.nasa.gov.
2. "NASA Study Provides Next Step to Establishing Lunar Outpost," NASA News Release, June 24, 2008, www.nasa.gov/home/hqnews/2008/jun/HQ_08155_LCCR.html
3. "NASA Lunar Probe Undergoing Final Checks," Space News, June 30, 2008, p. 8.
4. Craig Covault, "Mars Like Earth: Phoenix finds Martian soil chemistry could support life," Aviation Week and Space Technology, June 30, 2008, p. 37.
5. U.S. National Space Policy, Office of Science and Technology Policy, 2005.
6. Global Exploration Strategy, December 2007, www.nasa.gov/home/hqnews/2007/may/HQ_07126_Exploration_Framework.html.
7. NASA 2006 Strategic Plan, www.nasa.gov/audience/forpolicymakers/index.html.
8. Exploration Systems Mission Directorate Work Assignments, October 30, 2007, www.nasa.gov/mission_pages/constellation/main/constellation_workforce.html
9. "Mission Operations at Marshall Space Flight Center: A Brief History," NP-2006,04-47-MSFC.
10. *Marshall Space Flight Center: 1960 to 1985, 25th Anniversary Report*, NASA 25M1285.
11. "NASA opens Space Station science command post," NASA News Release, February 2, 2001.
12. "The Payload Operations Center: Integration and Management of Space Sation Science Operations at NASA's Marshall Space Flight Center," NASA Fact Sheet, March 2001, http://www.nasa.gov/centers/marshall/news/background/facts/POC.html
13. "Space Station Hardware and Life Support," www.nasa.gov/centers/marshall/shuttle_station/hardware.html.
14. "NASA researchers launch handheld LOCAD-PTS to be tested aboard the International Space Station," http://locad.nasa.gov/
15. Michael Taverna, "Return of Jules Verne: Europeans jump on bandwagon for independent crew transportation system," Aviation Week and Space Technology, June 16, 2008, p. 40.
16. "NASA and ESA Complete Comparative Exploration Architecture Study," NASA News Release, July 9, 2008, www.nasa.gov/home/hqnews/2008/jul/jul/HQ_08171_NASA_ESA_Architecture_Study.html

National Aeronautics and Space Administration

Building on 50 Years of Mission Operations Experience for a New Era of Space Exploration

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NASA Marshall Space Flight Center

AIAA Space 2008

September 9–11, 2008

Agenda

- Sustainable Exploration Solutions
- Ares I and Ares V
- NASA's Constellation Program Manages the Exploration Architecture
- The Mission Operations Laboratory's Legacy of Success
- Space Shuttle and Spacelab Support
- International Space Station Science Operations
- The Payload Operations Center
- International Partner Sites
- Planning the Ares I Operations Concept

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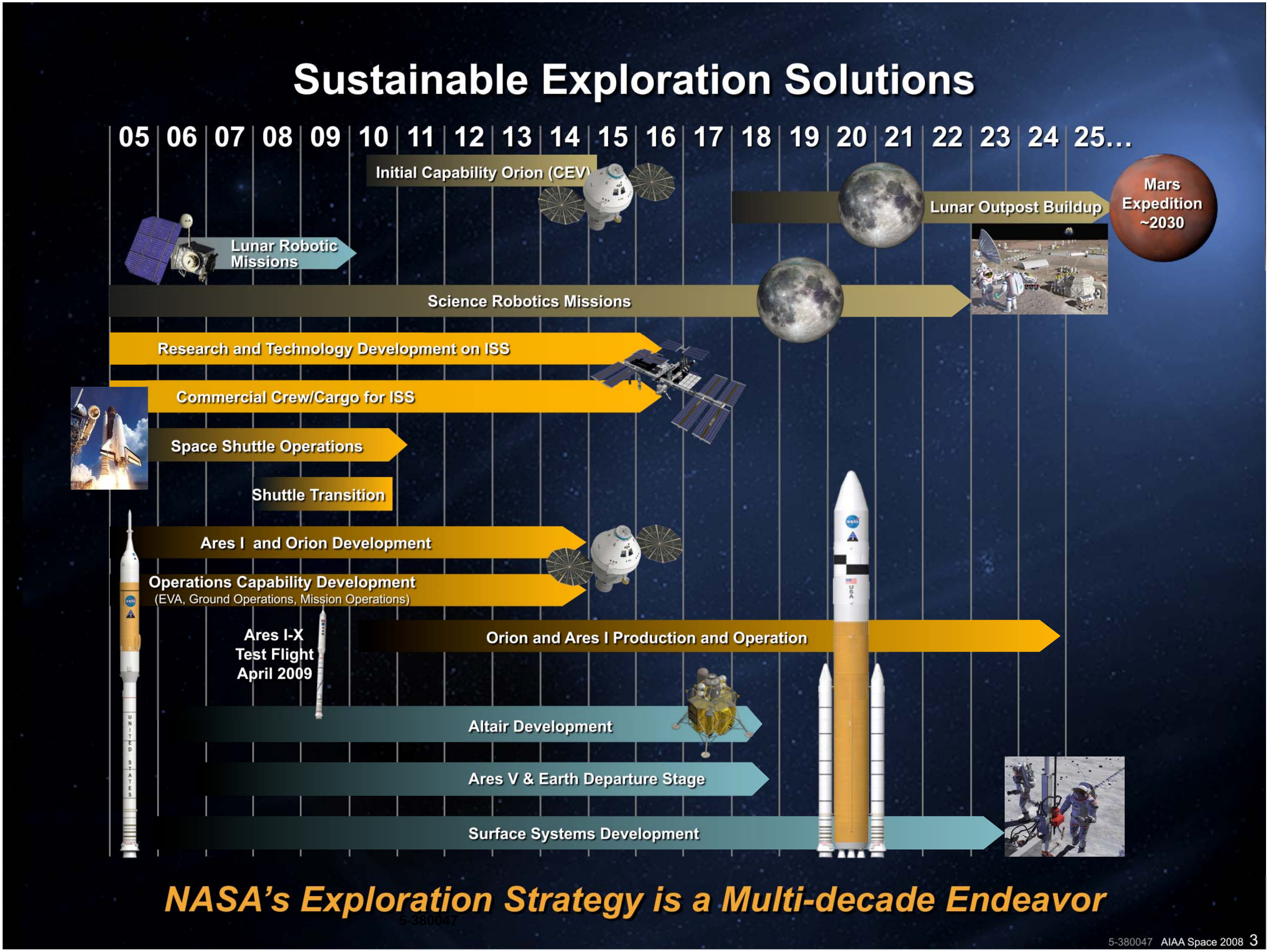
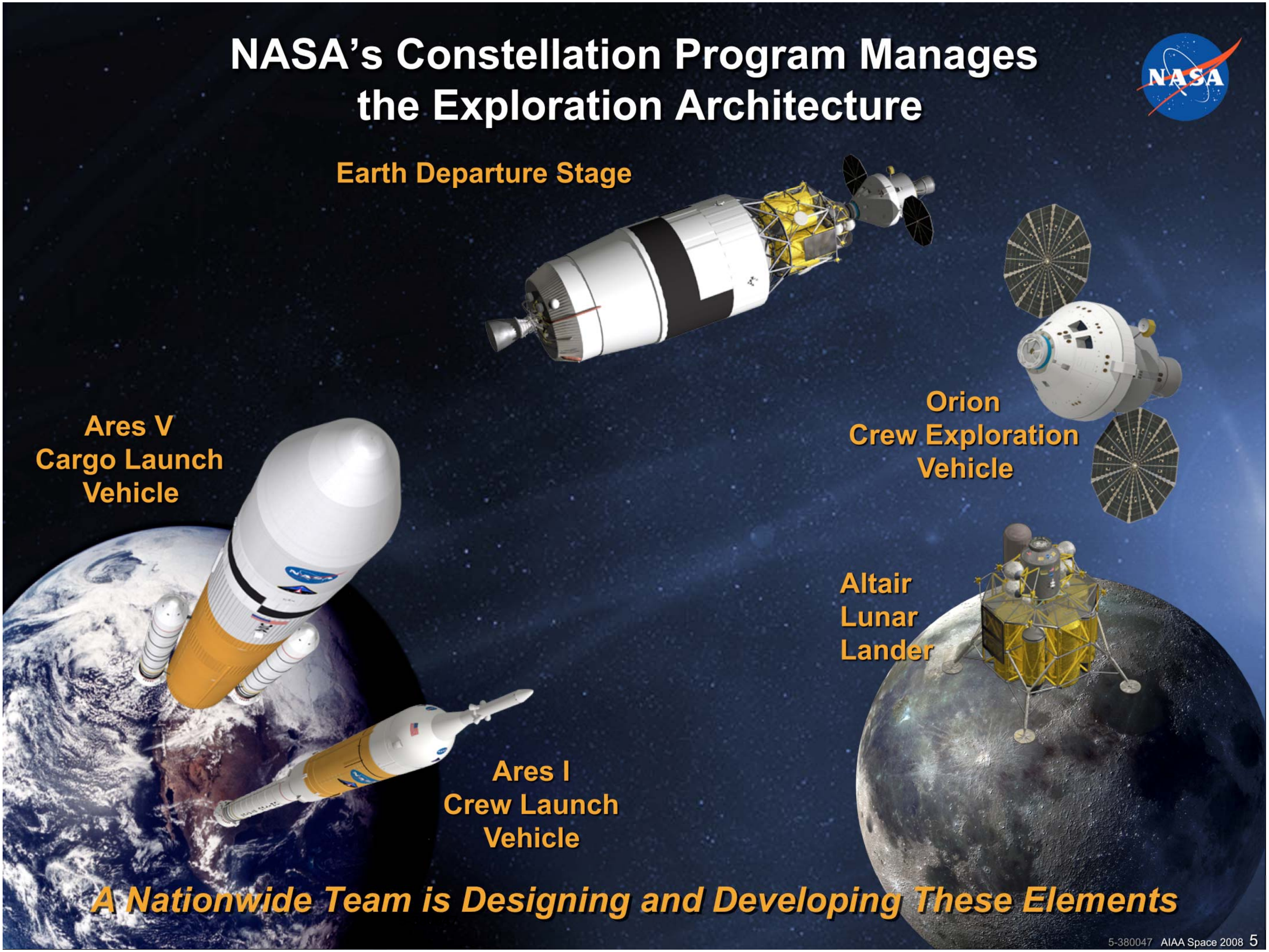


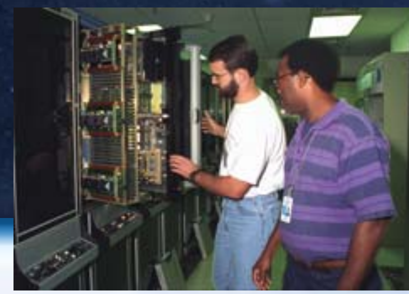
Sustainable Exploration Solutions
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25…
Initial Capability Orion (CEV)
Lunar Outpost Buildup
Mars Expedition ~2030
Lunar Robotic Missions
Science Robotics Missions
Research and Technology Development on ISS
Commercial Crew/Cargo for ISS
Space Shuttle Operations
Shuttle Transition
Ares I and Orion Development
Operations Capability Development
(EVA, Ground Operations, Mission Operations)
Ares I-X
Test Flight
April 2009
Orion and Ares I Production and Operation
Altair Development
Ares V & Earth Departure Stage
Surface Systems Development
NASA's Exploration Strategy is a Multi-decade Endeavor
5-380047 AIAA Space 2008 3

Ares I and Ares V

Safe, Reliable, and Cost-effective Solutions


NASA's Constellation Program Manages the Exploration Architecture
NASA
Earth Departure Stage
Orion Crew Exploration Vehicle
Ares V Cargo Launch Vehicle
Altair Lunar Lander
Ares I Crew Launch Vehicle
A Nationwide Team is Designing and Developing These Elements

The Mission Operations Laboratory's Legacy of Success



50 Years of Aerospace Support

Space Shuttle and Spacelab Support

Supporting Space Shuttle Launches and Science for Almost 30 Years

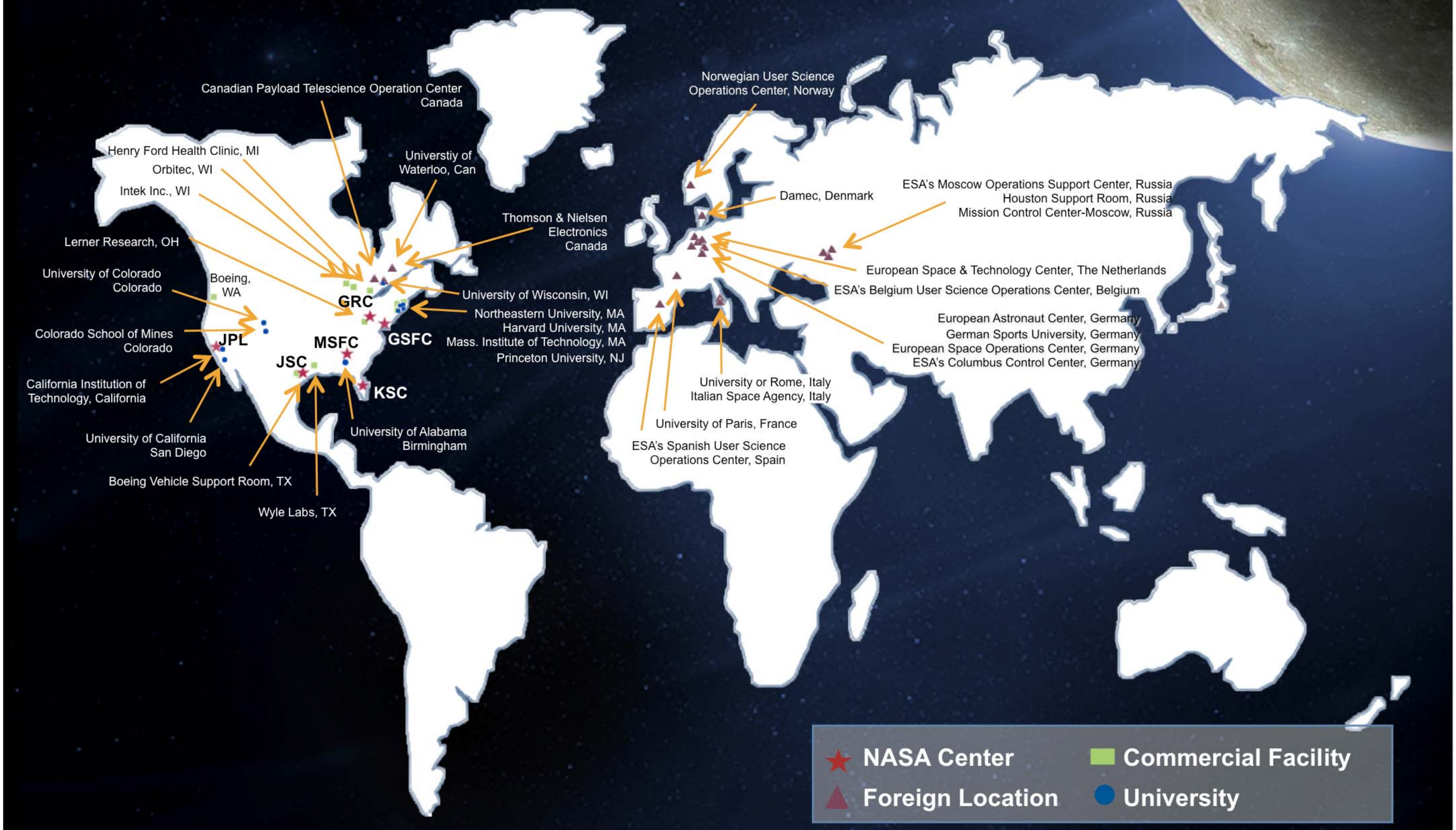
International Space Station Science Operations: A Foundation for Future Exploration

One-of-a-Kind Infrastructure Asset

The Payload Operations Center

Supporting Science on the Station 24/7

International Partner Sites



Connecting Remote Scientists and Coordinating Payload Activities

Planning the Ares I Operations Concept

Developed by Mission Operations in partnership with the JSC Mission Operations and KSC Ground Operations Projects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