Human Exploration and Operations Committee

NASA Advisory Council

March 1, 2022

N. Wayne Hale, Jr.

HEO Committee meetings and Focus

- HEO Committee meet virtually January 18-19, 2022
  (first meeting in a year)
- HEO Committee membership

Returning	New
Nancy Ann Budden	Kwatsi Alibaruho
James Voss	George Sowers
Mark McDaniel	Doug Ebersole
Pat Condon	Lynn Cline
Pat Saunders (ex officio)	
Mike Lopez-Alegria (absent this time)	

- Focus from the Administrator
  1. Climate Change
  2. Commercial and Industry Partnerships
  3. Diversity , Inclusion , Equity and Accessibility
  4. International Collaboration
  5. Program Management and Acquisition

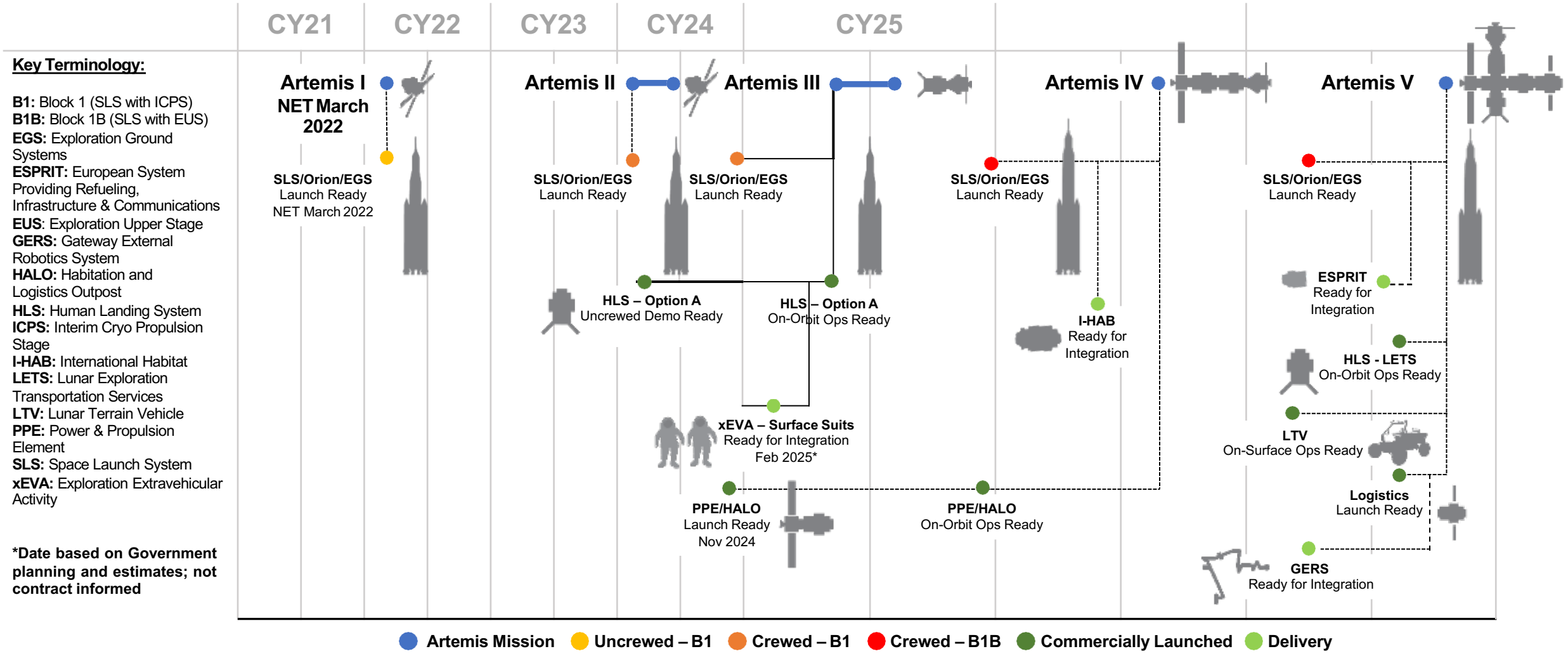
Mission Directorate Reorganization

In September 2021, NASA Administrator Bill Nelson announced the agency was creating two new mission directorates that would best position the agency for the next 20 years. The move separated the Human Exploration and Operations Mission Directorate (HEOMD) into the new **Exploration Systems Development Mission Directorate (ESDMD)** and **Space Operations Mission Directorate (SOMD)**.

The changes were made because of increasing space operations in low-Earth orbit and development programs well underway for deep space exploration including Artemis missions.

The intent for creating two separate mission directorates was to ensure these critical areas have focused oversight teams in place to support and execute for mission success. This approach also allows one mission directorate to operate in space while the other builds future space systems, so there is a constant cycle of development and operations to advance NASA's goals in space exploration.

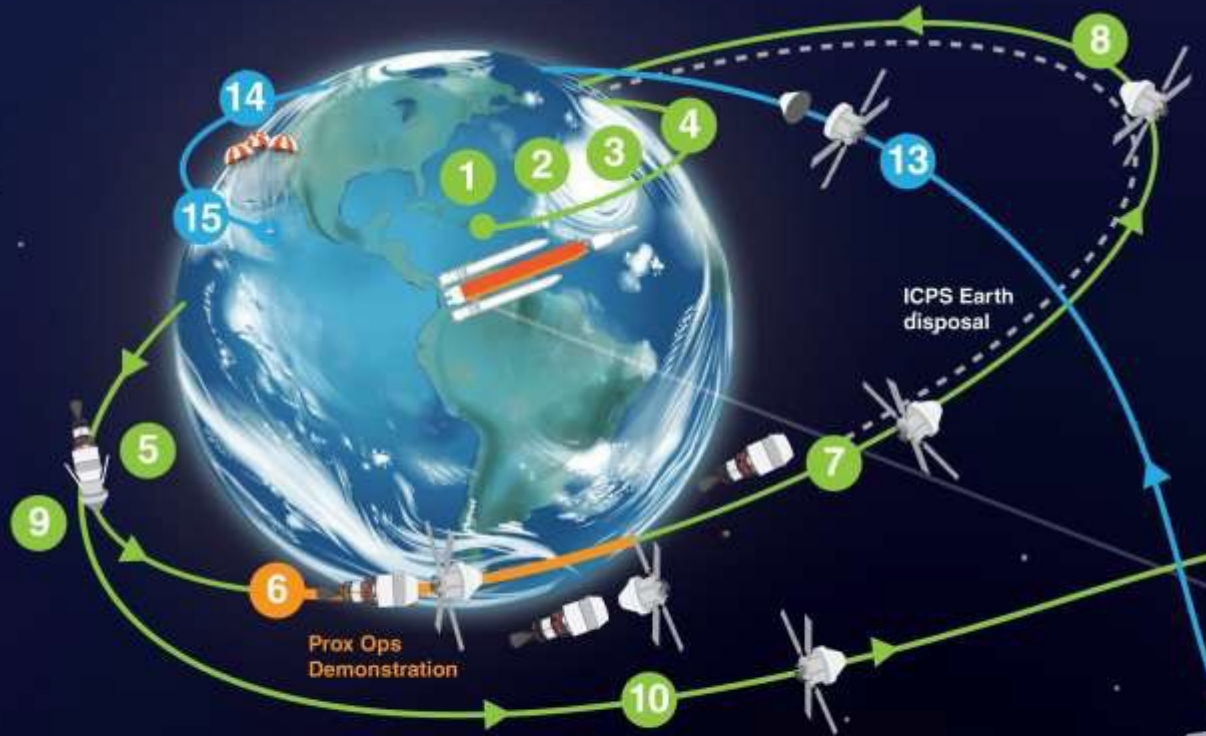
Working Manifest for Technical Integration



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. **LAUNCH**
   SLS and Orion lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **EARTH ORBIT**
   Systems check with solar panel adjustments.
6. **TRANS LUNAR INJECTION (TLI) BURN**
   Maneuver lasts for approximately 20 minutes.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
   ICPS commits Orion to moon at TLI.
8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
   As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
9. **OUTBOUND POWERED FLYBY (OPF)**
   60 nmi from the Moon; targets DRO insertion.
10. **LUNAR ORBIT INSERTION**
    Enter Distant Retrograde Orbit.
11. **DISTANT RETROGRADE ORBIT**
    Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.
12. **DRO DEPARTURE**
    Leave DRO and start return to Earth.
13. **RETURN POWERED FLYBY (RPF)**
    RPF burn prep and return coast to Earth initiated.
14. **RETURN TRANSIT**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**
16. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
17. **SPLASHDOWN**
    Pacific Ocean landing within view of the U.S. Navy recovery ship.



ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1. **LAUNCH**
   Astronauts lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **APOGEE RAISE BURN TO HIGH EARTH ORBIT**
   Begin 24 hour checkout of spacecraft.
6. **PROX OPS DEMONSTRATION**
   Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN**
8. **HIGH EARTH ORBIT CHECKOUT**
   Life support, exercise, and habitation equipment evaluations.
9. **TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
   Lunar free return trajectory initiated with European service module.
10. **OUTBOUND TRANSIT TO MOON**
    4 days outbound transit along free return trajectory.
11. **LUNAR FLYBY**
    4,000 nmi (mean) lunar farside altitude.
12. **TRANS-EARTH RETURN**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
13. **CREW MODULE SEPARATION FROM SERVICE MODULE**
14. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
15. **SPLASHDOWN**
    Ship recovers astronauts and capsule.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

Initial Human Landing System

Appendix H Option A: Uncrewed Demo and first Crewed Landing

APR 2021 ● SpaceX selected for Option A (DDT&E and first crewed demonstration mission)

JULY 2021 ● Option A Contract Award

NOV 2021 ● US Court of Federal Claims upholds SpaceX Selection, contract resumed

- First five SpaceX milestones complete; very strong data packages/reviews
- Milestone schedule updated in the contract
- Updated Integrated Master Schedule received and under evaluation
- Site visits to Boca Chica and Hawthorne showed significant Starship progress

TBD 2022 Upcoming Milestone: Orbital Flight Test

Image Credit: SpaceX

Additional HLS Procurement Actions

Appendix N

- Prepares industry for the transportation services competition (also called a “bridge”)
- Initial awards to five companies: Blue Origin, Dynetics, Lockheed Martin, Northrup Grumman, and SpaceX
- CLIN 1 completed Nov 2021: Industry assessment of draft sustaining lander requirements
- Initially awarded CLIN 2 Risk Reduction work under way (initial awards based upon available funding)
- Additional work (CLINs 2, 3 and 4) may be awarded based upon available funding

HLS Lunar Exploration Transportation Services (LETS)

- Develop and certify at least one affordable lunar landing solutions for sustained transportation services
- Two Request for Information (RFI) cycles completed to date in addition to App N
- DDT&E through Certification
  - Includes an uncrewed test of the human landing system
  - Contractor/Provider responsible for obtaining the launch vehicle
  - CLINS (severable) for Large Cargo missions; (not competing with GLS or CLPS)
- Services
  - Schedule: Recurring missions beginning 2028
  - IDIQ task orders for NASA determined mission assignments (includes flight readiness, post-flight review, etc.)
- Draft RFP to be available Spring, 2022

Exploration Extravehicular Activity (xEVA) Status

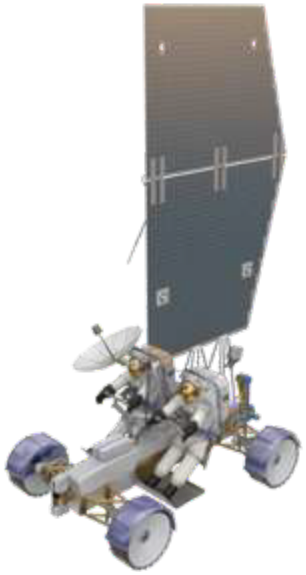
xEMU DVT Helmet Light Testing

xEMU Antenna Testing

- xEVA Services (xEVAS) procurement to provide suits for ISS, Gateway and the lunar surface
  - Proposals received on Dec 14th, 2021
  - Targeting contract award April 2022
- Continued strong government-based risk reduction work
  - Initiated exploration Extravehicular Mobility Unit (xEMU) design verification testing (DVT) of the pressure garment subsystem (PGS) and portable life support subsystem (PLSS)
    - Primary and auxiliary Thermal Control Loop testing
    - Helmet light and camera assembly vibration testing
    - Antenna pattern testing
    - PGS partial gravity mobility evaluations at Active Response Gravity Off-load System facility (ARGOS)
  - Successfully completed first human-in-the-loop test series in upgraded 20ft Chamber test facility
  - Successfully completed fifth of six planned on-orbit simulated EVA series with the Spacesuit Evaporation Rejection Flight Experiment (SERFE) following a planned 210d dwell period
  - Test data and reports will be added to EVA Technical Library to reduce risk for future xEVAS partner(s)

Human Surface Mobility (HSM) Status

- Released a second Lunar Terrain Vehicle (LTV) Request for Information in September 2021
  - Received 21 responses containing feedback on approaches to surviving the extended lunar night, supporting 10 years of operation, delivery service preference, and interest in providing LTV as a commercial service.
  - Responses are feeding updates to the Survive the Night assessment and informing LTV procurement strategy.
- Completed initial draft of requirements and initial standards tailoring to support upcoming LTV Mission Concept Review (MCR), including those for LTV system and interfaces to xEVA, HLS, communication systems, and payloads.
- Investigated strategies for changes to LTV Reference Design power and thermal subsystems for surviving longer periods of lunar night
- Held a three-day TIM with JAXA to discuss Pressurized Rover high-level system requirements and concepts of operation, as a part of the ongoing feasibility study
- Initiated an AES cross-program analysis to assess impacts of incorporating a suitport requirement for sustained lunar surface operations.
  - A final decision on the requirement is expected in early spring and programmatic documentation will be updated accordingly



ISS Research Statistics

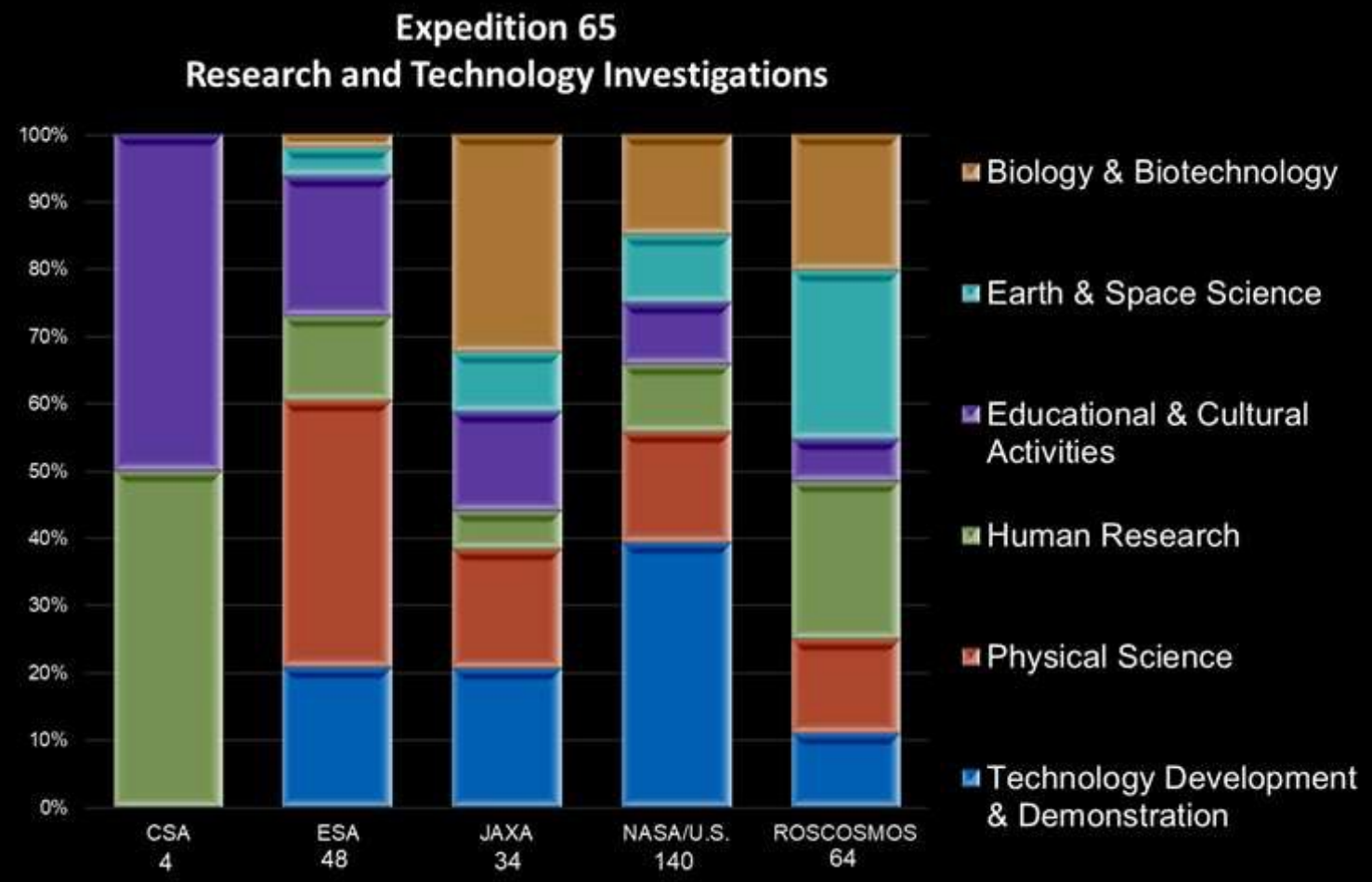
Investigations for 65: 290

- 140 NASA/U.S.-led investigations
- 150 International-led investigations
- 81 New Investigations
  - 0 CSA
  - 24 ESA
  - 11 JAXA
  - 43 NASA/US
  - 3 ROSCOSMOS

MCB Approved Statistics Exp. 0-62

- 3040 Investigations
- 4418 Investigators Represented
- 109 Countries/Areas with ISS Research and Education Participation
- Over 2377 Scientific Results Publications (Dec 1998 – Nov 2021)

Estimated Number of Investigations Expedition 0-65: 3202*



*Pending Post Increment Adjustments

2021 Utilization Highlights

Benefits to Humanity

Storm Spotting

The **Crew Earth Observations** activity records how the planet is changing over time, from human-caused changes, such as urban growth and reservoir construction, to natural dynamic events, such as hurricanes, floods, and volcanic eruptions.

Protein Crystal Growth

The biotechnology study seeks to demonstrate new methods for producing high-quality protein crystals in microgravity and identify possible targets for drugs to treat diseases on Earth.

Utilization Transition from ISS to CLD (notional)

Users	ISS	CLD
International Partner Utilization	Through ISS Intergovernmental Agreement (IGA) and bilateral agreements	Bilateral government to government agreements and arrangements directly with industry
NASA Technology Demonstration	Long-duration microgravity testing of exploration systems (ECLSS, Crew Health Systems, Food Production, etc.)	Accommodation for ongoing subset of testing, possible incorporation into CLD designs
NASA Human Research	HRP risk reduction plans - multiple subjects for varied durations	Ongoing research with NASA crew and possibly private astronauts, exploration analogs
NASA Science	Biological, Physical, Earth, Planetary decadal-driven science	Purchase accommodation for ongoing decadal-driven science; transfer hardware or purchase commercial facility services
Other Government Agency Research	Through ISSNL or NASA collaboration (NIH, NSF, DoD, others)	Through LEO National Lab
In-Space Product Manufacturing	NASA in-space production + ISSNL	Development through LEO National Lab ; commercial production business to business
Commercial Tourism, Marketing	ISS Private Astronaut Missions, Commercial Use Policy, reimbursement of resources	Business to business

Vision for LEO Economy:
A World of New Possibilities

- NASA is one of many customers in a robust low-Earth orbit (LEO) economy
- Commercially-owned and operated transportation for cargo and crew
- Commercially-owned and operated LEO destinations that are safe, reliable, and cost-effective
- Regular production, distribution, and trade of goods and services
- Ongoing research and science activities including a LEO National Lab
- Continuation of human spaceflight exploration objectives
- Sustained presence and U.S. leadership in LEO

COMMERCIAL CARGO & CREW TRANSPORTATION

Operational

Northrop Grumman

SpaceX

Final Dev

Sierra Space

Operational

SpaceX

Final Dev

Boeing

Concept Maturation

Sierra Space

Blue Origin

COMMERCIAL LEO DESTINATIONS

Notional

Axiom

More Elements of a Strong LEO Economy

Private Astronaut Missions & Space Tourism

Commercial Marketing, Advertisement & Entertainment Activities

Inspiration for Student STEM Activities

In-Space Manufacturing & Production

LEO National Lab

Technology Demonstrations

Human Research

Commercial Destination Free-Flyers

Company: **Nanoracks**, with Lockheed Martin and Voyager Space

Award: $160M

Overview: Starlab – large inflatable habitat and a metallic docking node, power and propulsion element, and external robotic arm.

Description:

- Four main operational departments: a biology lab, plant habitation lab, physical science and materials research lab, and an open workbench area.
- Provide approximately 1/3 of ISS's habitable volume.
- Achieve a CDR-level of maturity.

Company**: Northrop Grumman**, with Dynetics

Award: $125.6M

Overview: Three integrated metallic pressure vessels initially, with 3 docking ports.

Description:

- Habitat Modules derived from Habitation and Logistics Outpost (HALO) and Cygnus structures.
- Service Module evolved from the Cygnus cargo vehicle, with a larger structure and increased propellant capacity.
- Modules are supplemented with Cygnus designed for long-term stays.
- Provides for multiple internal and external payloads.
- Achieve a PDR-level of maturity.

Company: **Blue Origin**, with Sierra Space

Award: $130M

Overview: Orbital Reef – provides zoned utilization, large volume and hatchways, highly automated operations, and assembly without spacewalks.

Description:

- Microgravity research laboratory; experiment airlock; exposed payload locations; external robots; and extravehicular activity capabilities.
- Provide approximately 90% of ISS's habitable volume.
- Achieve a Critical-Design-Review (CDR)-level of maturity.

Private Astronaut Missions (PAMs)

- Private Astronaut Missions are commercial missions (no NASA personnel) to the ISS with full responsibility and liability resting on the Commercial Provider for mission success and crew safety (except when docked to ISS).
- NASA responsibility is solely based on protecting the ISS and ISS crew and providing limited services to enable the PAM.
- NASA enabling up to two short-duration PAMs to ISS per year.

- Axiom Space selected for first PAM (Ax-1)
  - Targeted for February 28, 2022.
  - 10 days total mission duration, using a Falcon 9/Dragon.
  - Crew conducting research, outreach and technology demos.

Ax-1 Prime Crew

- Axiom Space recently selected for PAM-2 targeted for late 2022/early 2023. NASA did not make a PAM-3 selection at this time.

Commercial Human Spaceflight Concerns

What's Needed	Mission phase	Concern
Human Safety Requirements	*Pre-Launch & Launch*	No commercial industries standards & processes for Human Space Flight (occupant safety)
		No clear agency reviewing occupant safety requirements compliance
		Lack of Government Certification
		Use of CCP requirements in 1130, 1120 and 1150 may be too restrictive for pure commercial missions.
Eliminate redundancy and address gaps in Ground Safety and Public Safety requirements	*Pre-launch & Launch*	Overlapping oversights at federal ranges/NASA sites for ground safety (pre-launch) and public safety (launch)
Export Control	*Pre-Launch & Launch*	Assess potential concerns associated with commercial vehicles used for both Government and private missions
Proprietary Data Release	*Pre-Launch & Launch*	Assess potential concerns associated with commercial vehicles used for both Government and private missions
Technical Expertise/Service only exists within the government or with few commercial providers	*Pre-Launch & Launch*	Flight safety analysis expertise is limited to a few entities
		Emergency Rescue – DoD Search and Rescue services not available to commercial mission
		Continuous Communication - Limited availability for Commercial Providers to utilize heritage HSF communication systems (i.e., S-band & TDRSS)
		Non-Continuous Communication – Use of commercial ground stations/ frequencies (KA, L-Band, X-band) do not provide continuous communications due to no ability to prioritize coverage in public spectrum ranges.

RECOMMENDATIONS AND FINDINGS

2 HEO COMMITTEE RECOMMENDATIONS TO AAs

Short Title of Recommendation: Financial Commitment to the Commercial LEO Destinations (CLD)

Recommendation: NASA should determine its demand for LEO services as soon as practical, but well in advance of ISS retirement. This demand should be translated into a contractual commitment as soon as practical. NASA should begin transitioning its needs to the commercial providers well before the ISS is retired.

Major Reasons for the Recommendation: Business viability of the CLDs is as important as technical viability. The CLD contractors will regard NASA as an anchor tenant. A firm commitment by NASA will be essential in enabling the CLDs to attract additional customers and close the business case.

Consequences of No Action on the Recommendation: Long term availability of commercial LEO services depends on the business viability of the service providers. A lack of firm NASA commitment as a customer will dramatically reduce the business viability of the providers.

Short Title of Recommendation: All Mission Directorates Re-evaluate Program Schedules & Manifest Due to Pandemic Supplier Performance

Recommendation: Please be sure to assess those elements of the launch manifest and program development schedules for which material procurement is in the critical path and be sure that we have incorporate sufficient planning buffer to address the mid-pandemic supply base performance.

Major Reasons for the Recommendation: Due to the COVID-19 global pandemic and the impact on the global labor market, microchip availability, and general industry impairment, typical delivery lead times for material procurements are running between 2x – 5x of what is normal.

Consequences of No Action on the Recommendation: NASA's various projects with near and intermediate term material procurements may miss schedule commitments due to unforeseen and unmitigated delivery schedule and quality risks from key suppliers. Given the scale of the programs, significant schedule slips due to material procurements will have significant downstream cost impacts to the affected programs.