National Aeronautics and Space Administration

Artemis: We Are Going!

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NASA Johnson Space Center
AABI Annual Meeting, Denver, CO
July 18th, 2024

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- Powerful Intro Video ~5:00 minutes long

Apollo 8 Crew:
Frank Borman, Jim Lovell, and Bill Anders

Dr. Andrea Hanson

home

Lake Park, MN
Population 810

Grand Forks, ND
1997-2002

BS Chemical Engineering

Boulder, CO
2002-2009

MS & PhD
Aerospace Engineering

Seattle, WA
2009-2011

Post-Doc Orthopaedics &
Sports Med

Houston, TX
2011-Present

Johnson Space Center

Manager, Exercise, Physiology &
Countermeasures Lab

Exercise Countermeasures Operations
Integration Lead

Exploration Medical Capabilities System
Engineering Team

Portfolio Manager, Integrated CBS
(Central Nervous System/Behavioral
Health/Space Radiation)
Human Research Program

Crew Health and Performance Insight
Lead, HMTA, CrewCo HSI Discipline Lead
Human Landing System

SEI Office Rotation, EVA Human Surface
Mobility Program

Artemis Overview: Where, Why, When

Where: The Lunar South Pole

Artemis III Candidate Landing Regions

KEY LANDING REGION CONSIDERATIONS

Proximity to the South Pole

Gentle slope for landing and moonwalks

Constant view to Earth for communications

Continuous sunlight throughout the surface expedition of about 6.5 days

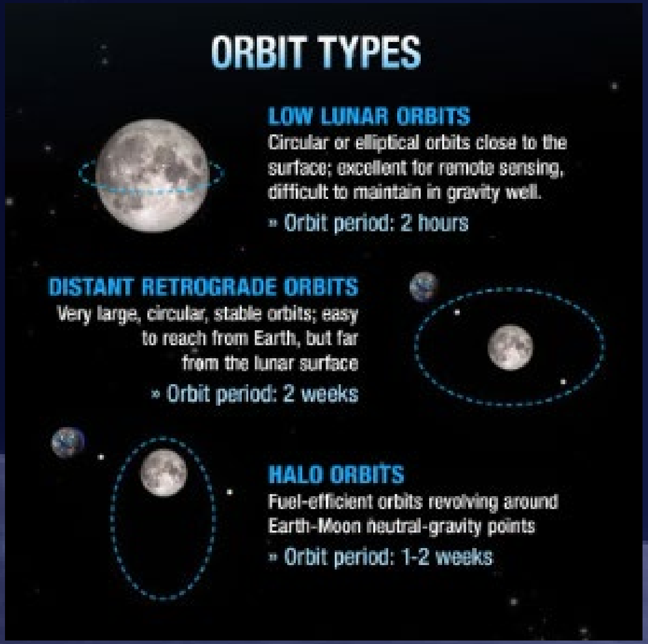
Landing Accuracy

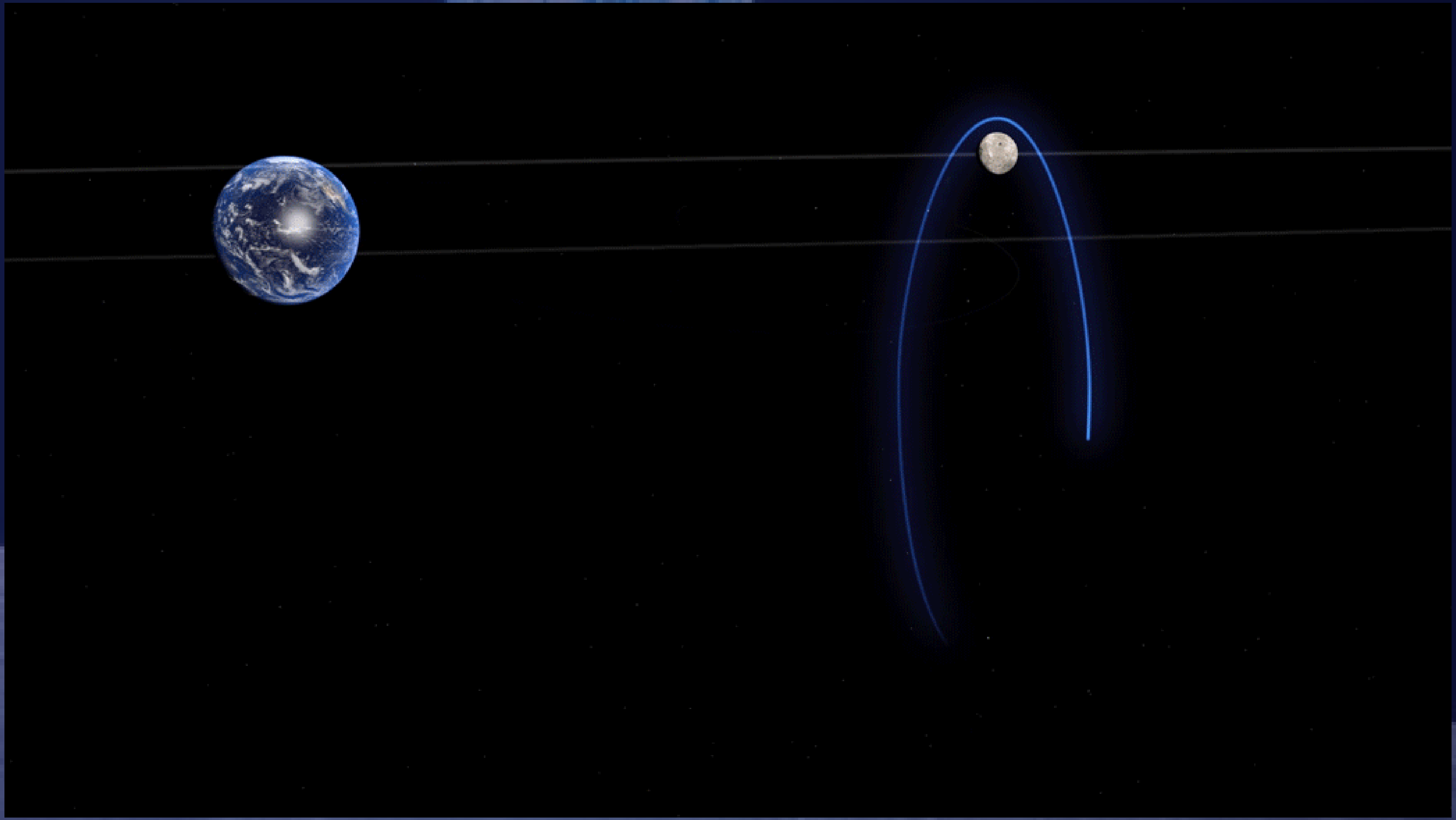
Surface data resolution

Combined mission vehicle capabilities: Space Launch System, Orion spacecraft, Starship Human Landing System

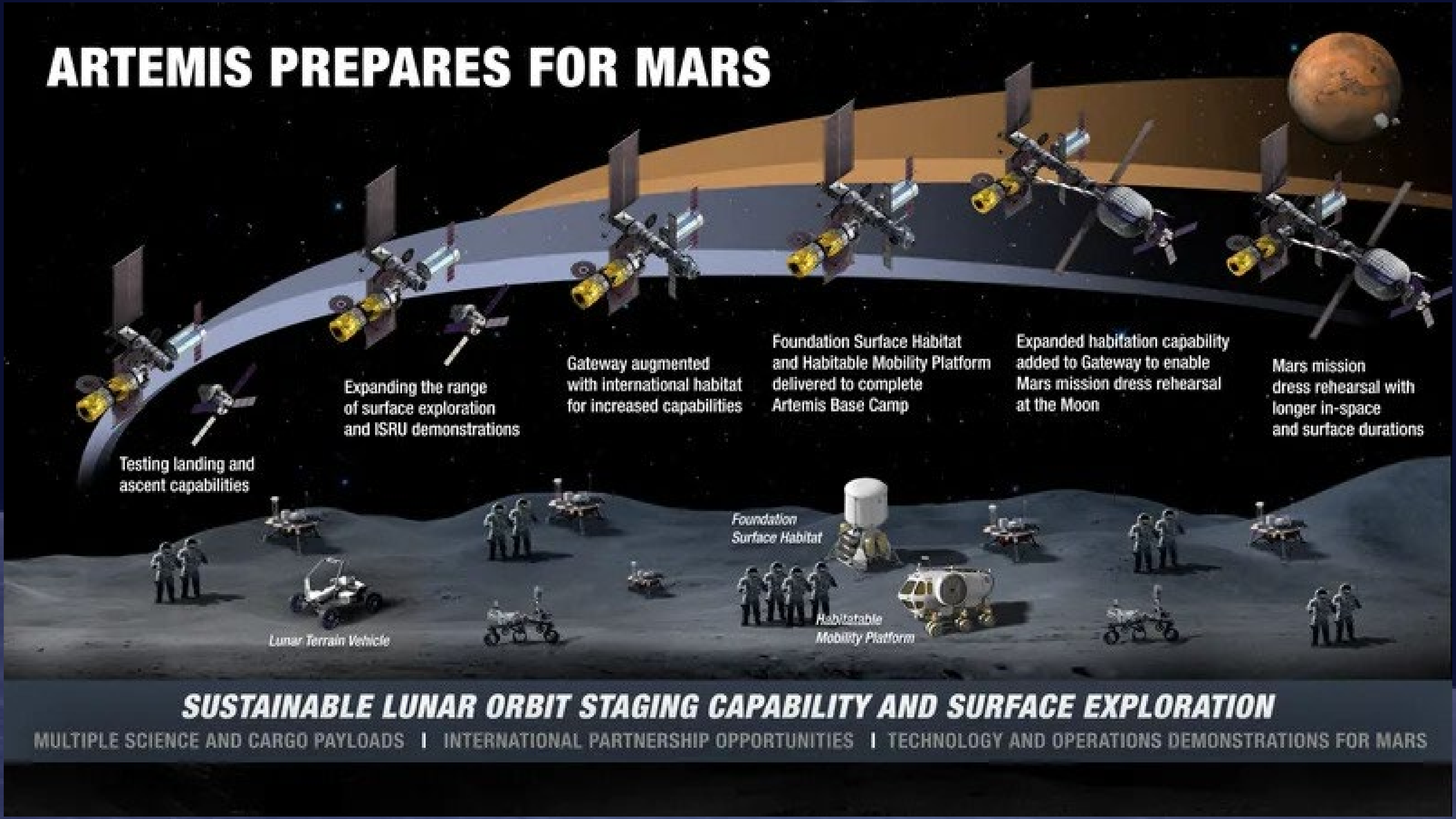
A landing *region* is approximately 15 km^2. Each landing region includes multiple potential landing sites.

Near Rectilinear Halo Orbit- NRHO: The Goldilocks Orbit



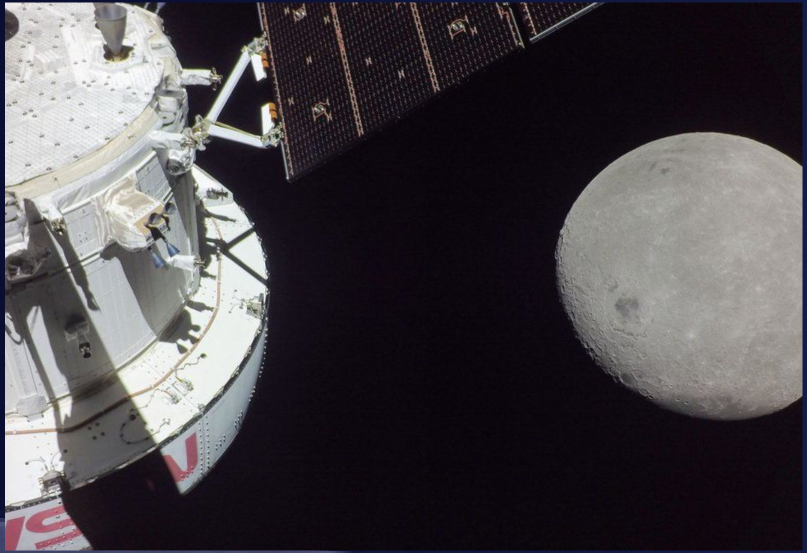


Artemis Overview: Why



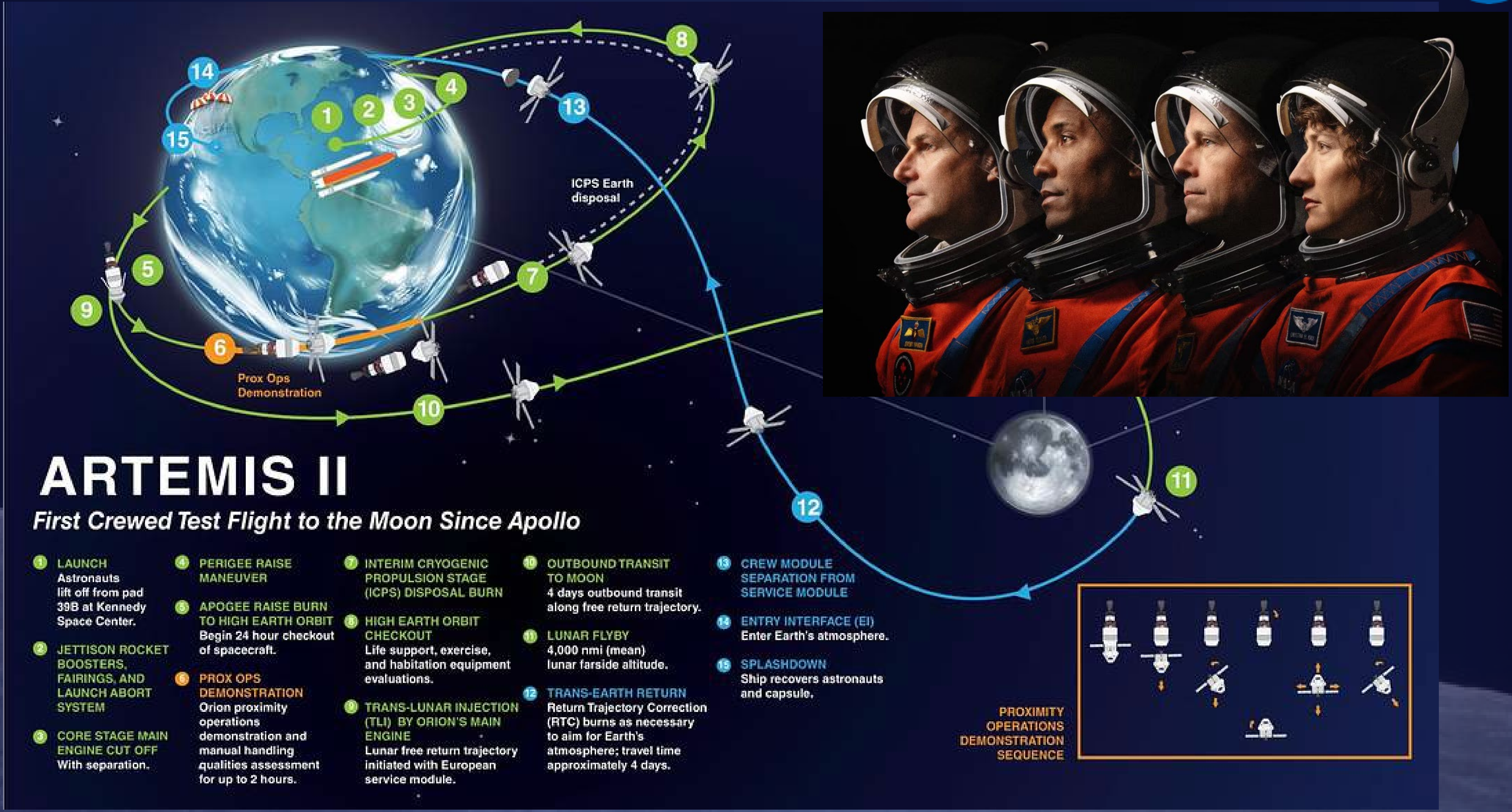
Artemis: When

Nov 16, 2022

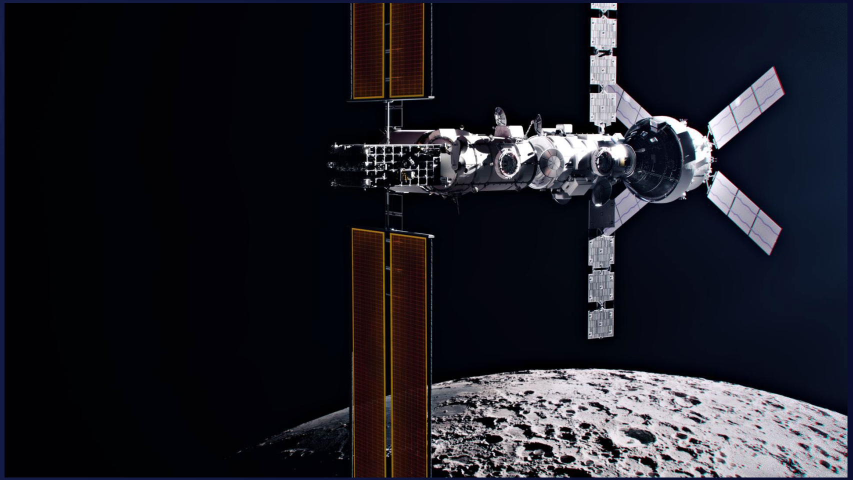


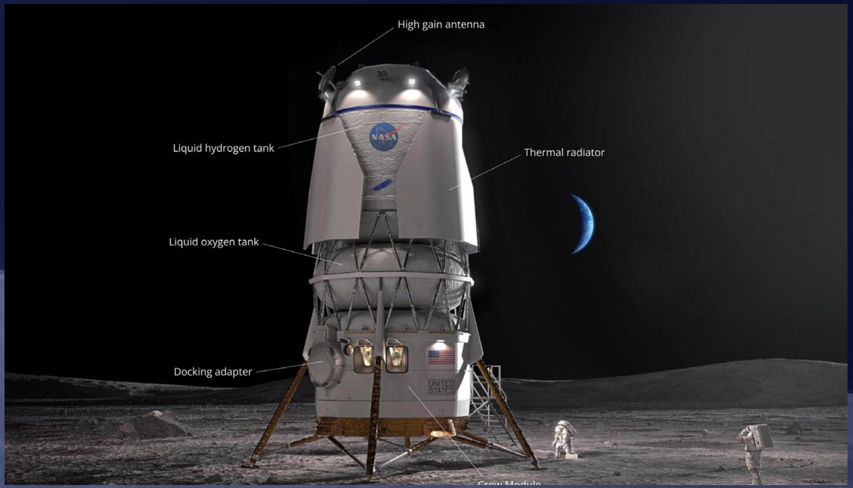
2026

Artemis II Crew: Hansen, Glover, Wiseman, Koch



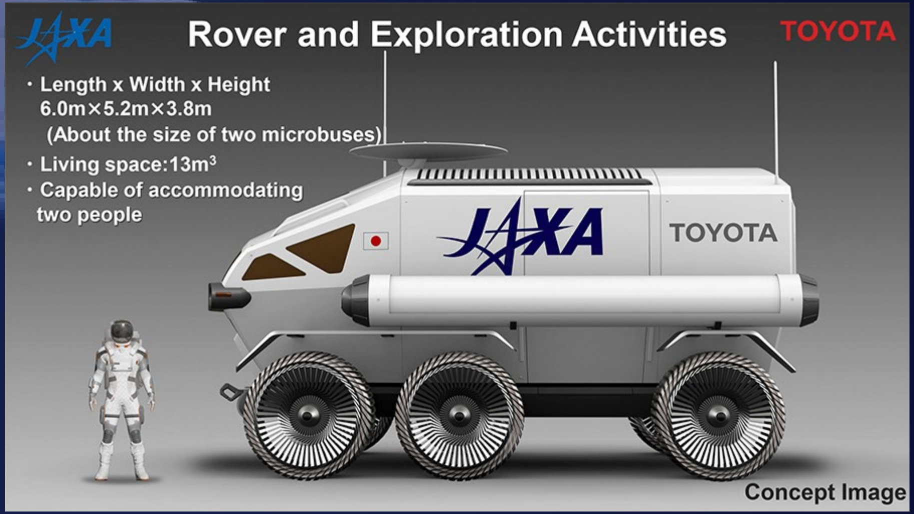
Artemis III & IV+





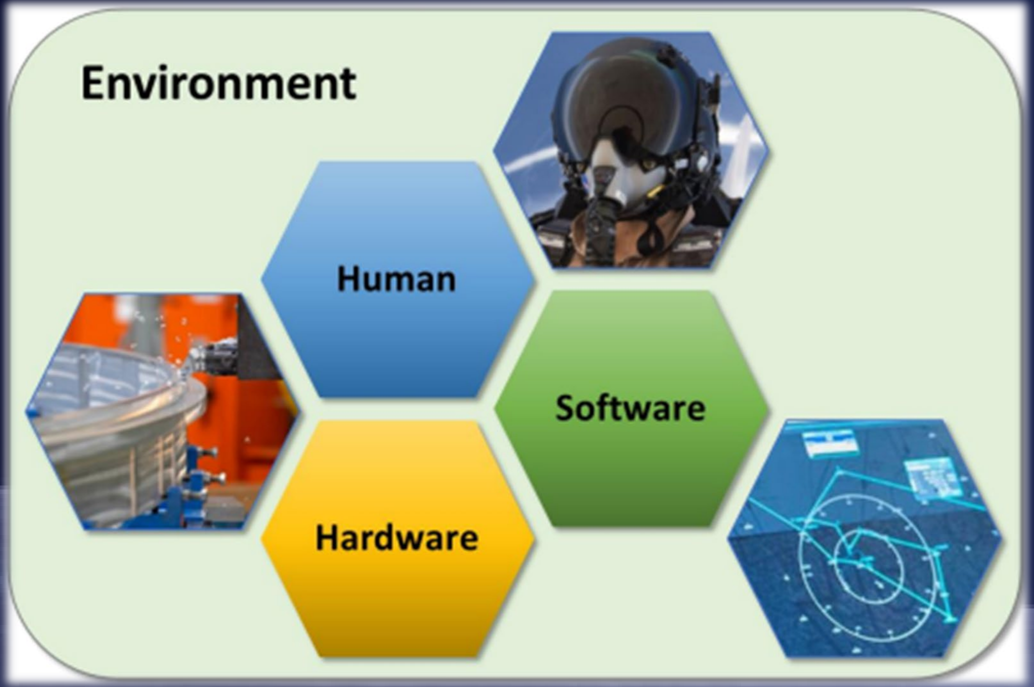
NASA and the World are going back to the Moon

This time to stay



The Artemis Accords are grounded in the Outer Space Treaty of 1967, outlining the vision and principles for a safe, transparent environment that facilitates exploration, science, and commercial activities for all of humanity to enjoy.

Human Systems Integration = Mission Success



HSI is a required interdisciplinary integration of the human as an element of a system to ensure that the **human** and **software/hardware** components cooperate, coordinate, and communicate effectively to successfully perform a specific function of mission.

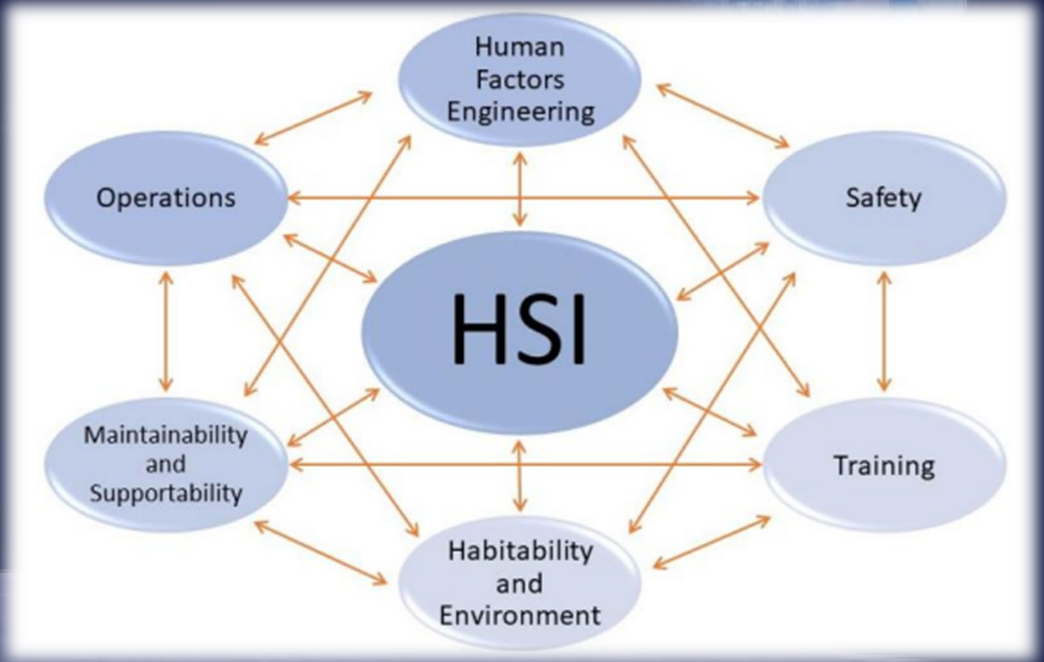
- **A philosophy:** By definition, HSI is a human centered mindset; a way of thinking instilled in those who design, build, and manage a system throughout its life cycle.
- **An approach to SE:** Those responsible for designing, testing, fielding, and managing systems must ensure human performance characteristics provide the foundation for SE.
- **A goal:** The goal of HSI is to optimize total system performance through effective human integration with system hardware and software while minimizing program costs and risks.

NASA HSI Domains Overview

Design for human-system interactions given human limitations and capabilities, and impacts of the operational environments on performance

Full life-cycle engagement of operational considerations into the design, development, maintenance and evolution of systems and organizational capability

Implementation of safety considerations across the full life cycle to reduce hazards and risks to personnel, system, facilities and mission.

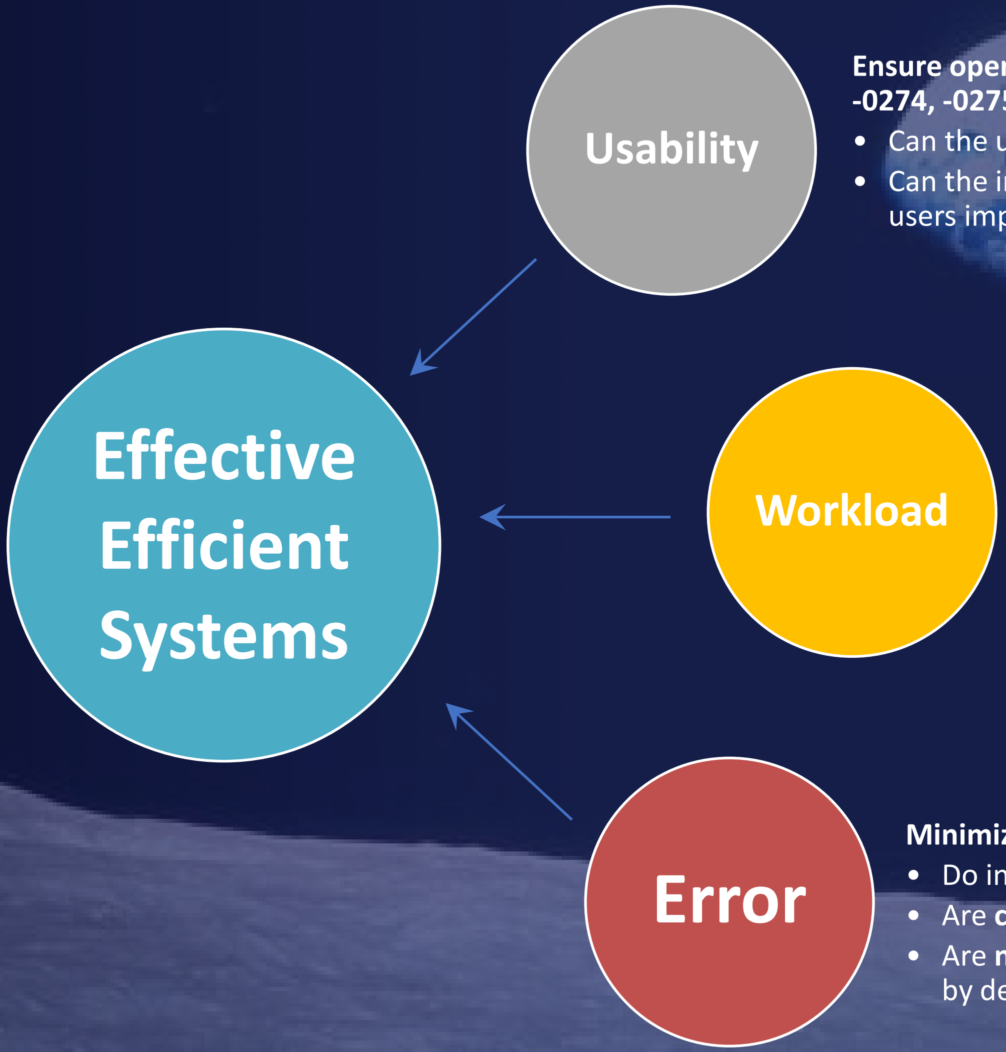


Designing for full life cycle and simplified maintenance and accessibility, reliability, optimized resources, spares, consumables and logistics given mission constraints

Design and implementation of effective training methods and resources to maximize human retention, retrieval and transfer, proficiency, and effectiveness to successfully accomplish expected an unexpected mission tasks, properly operate, maintain, and support the system and mission.

Ensuring system integration with the human through design and continual evaluation of internal/external living and working environments necessary to sustain safety, human and mission performance, and human health.

Design Effective & Efficient Systems



Ensure operational capability & timeliness (HLS-HMTA-0273, -0274, -0275, -0276)

- Can the user complete the task in/at **time** required?
- Can the interface & procedures be **used as designed** or do users improvise with alternate approaches?

Right-size workload (HLS-HMTA-0012, -0013)

- Can the user **cognitively** process all information sources and execute all actions necessary to successfully achieve complex or critical tasks within/at time required?
- Is **physical** workload acceptable for complex or critical tasks involving physical effort?

Minimize error (HLS-HMTA-0273, -0304)

- Do intentional user actions result in unintended outcome?
- Are **catastrophic errors eliminated** by design?
- Are **non-catastrophic errors mitigated** to acceptable frequency by design?

WHY

Does an effective & efficient design matter?

NASA Example: Collaboration with End-User = Success!

< "Before"

- Kits inside of Kits (design status quo)
- Highly organized but inflexible
- Harder to manifest and update for items with various expiration dates

"After" crew comments >

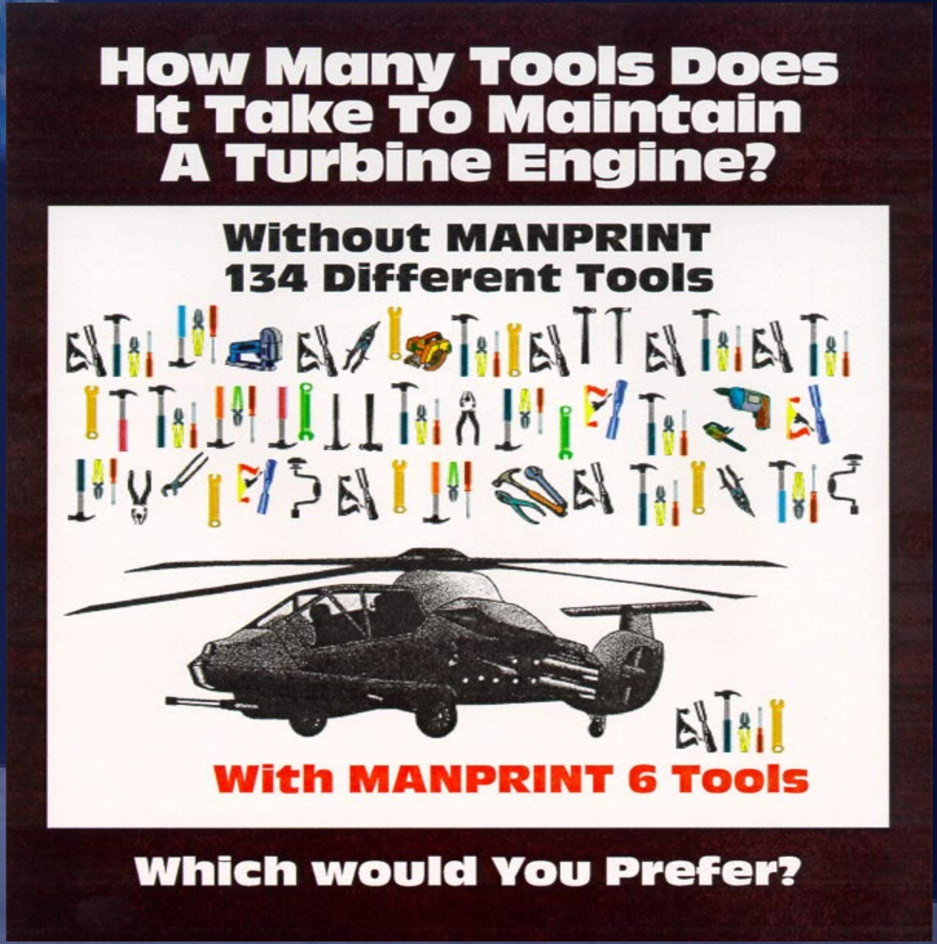
- One big, open kit!
- Kept functionality
- Increased flexibility
- Improved resupply
- Looks less organized but is effective

A "counter-intuitive" design solution may have the lowest sustaining cost.

A DoD HSI Success Story

Comanche Tool Kit

- The tool box for the T-53 series helicopter turbine engine (Huey & Iroquois) had 134 different tools.
- Because of MANPRINT and its inclusion of HSI in the design process, the tool KIT for the T-800 for the Comanche has <u>**six**</u> tools instead of 134
  - And the tools are inexpensive & commercially available
- **Result:**
  - Fewer tools
  - Less burden on the supply system
  - Less training and inventory time
  - Increased combat readiness

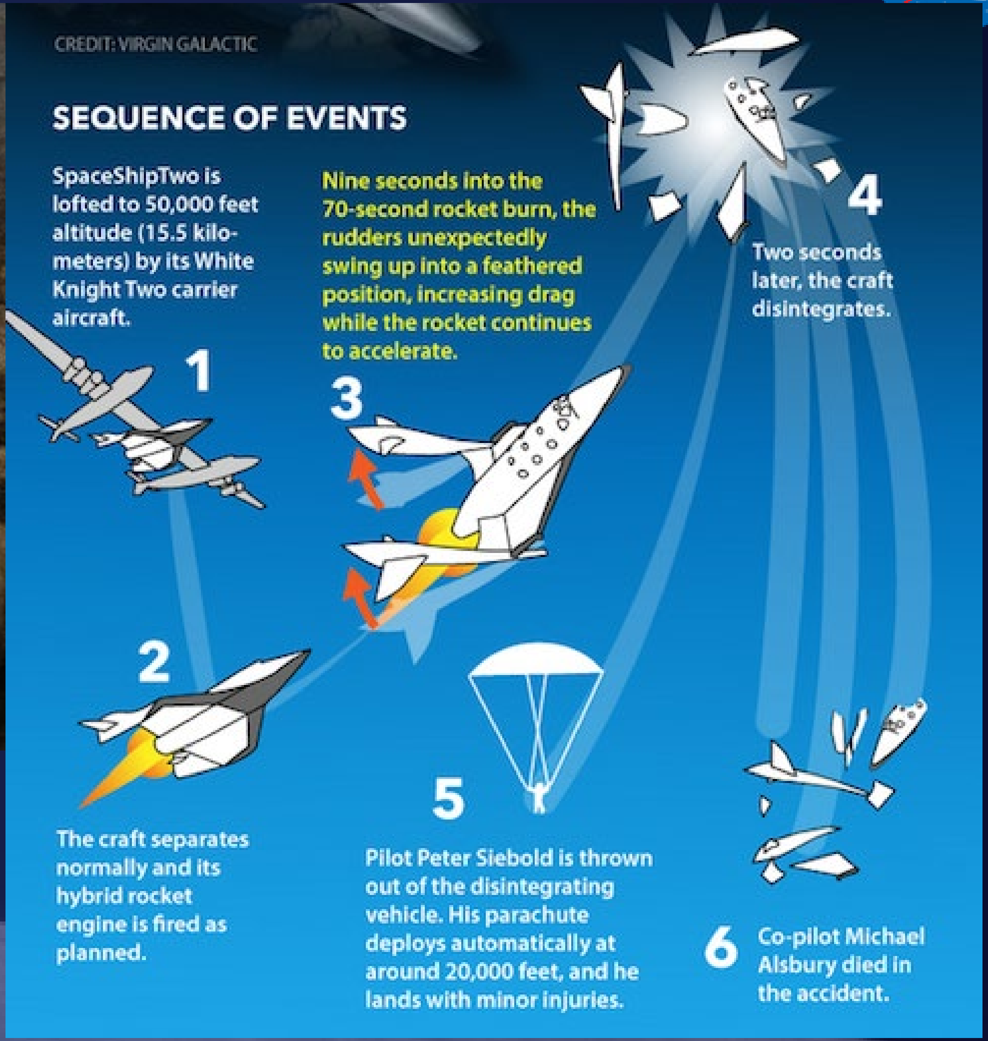


MANPRINT is the U.S. Army's Human Systems Integration Directorate

Human Factors Design Across the Artemis Fleet

Space X Dragon Flight Deck

NASA Orion Flight Deck



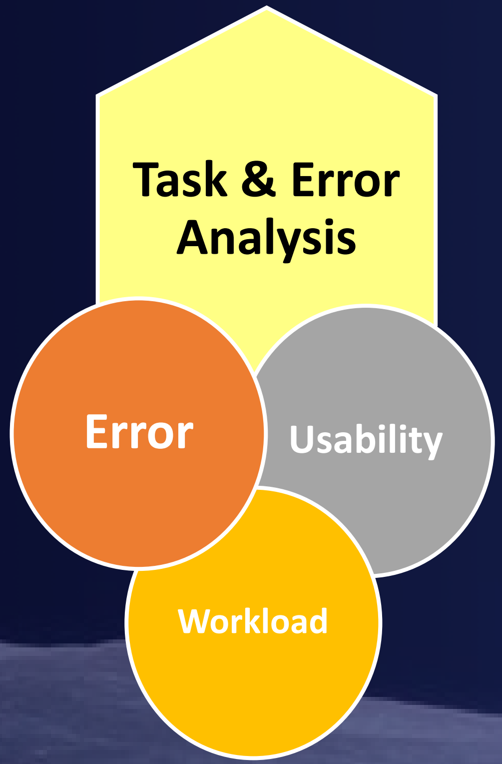
Virgin Galactic SpaceShip Two Failure

Root cause: Co-pilot error "premature repositioning" of the spacecraft's tail wings

No safeguards for human error

Adapted from [Introduction to HSI - NASA]

Virgin Galactic Space Ship Two



- Task & error analysis could have identified error potential for right action at wrong time
- Simulator testing could have identified inadvertent operation error potential
- Cognitive workload assessment could have identified unacceptable workload due to time & task stressors
- Design could have implemented control inhibit, two-step commanding, or reallocated task to flight SW

Notional Task & Error Analysis

1.0 Lunar Descent

2.0 Lunar Landing

3.0 Lunar Mission

2.0 Lunar Landing Tasks & Sub-Tasks		Crew #	Freq	Complexity	Critical Anthro	Strength	Restraint	Uniform	VisTask Type	Duration hh:mm:ss	Potential Error	Crit or Cat Haz
2.1	Prepare for Landing	1, 2										
2.2	Monitor System Performance	1			N/A	N/A	R	Suited Vent	Read	1:00	PE-1, PE-2	
2.3	Monitor Landing Events	1		Cx-2	N/A	N/A	R	Suited Vent	Read	0:30	PE-1	Cat
2.3.1	Override Landing			Cx-3	Thumb tip	N/A	R	Suited Vent	Read	0:00:60	PE-2, PE-3, PE-4	Cat
2.5	Respond to Depress	1, 2									PE-3, PE-4	Cat
2.4	Respond to Cabin Fire	2	O-N							0:30	PE-2, PE-3, PE-4	Cat
2.4.1	Access PFE	2	O-N	Cx-1	Thumb tip		R	Glove	ID	0:15		
2.4.2	Operate PFE	2	O-N	Cx-1	N/A	Grip	R					

Frequency
O-N Off-Nominal
NE Nominal per Event

Complexity
Cx-1 Not Complex
Cx-2 Moderately Complex
Cx-3 Highly Complex

Potential Error
PE-1 Failure to recognize out of limit
PE-2 Failure to act
PE-3 Wrong action at right time
PE-4 Wrong action at wrong time

Was out of limit condition correctly identified by crew?
Was correct action performed at correct time?
Was task correctly completed within time limit or time to effect?
- Was necessary information provided to crew at time of event?
- Was necessary information visible & understandable to crew?
- Were necessary controls evident to crew at the time needed?
- Were necessary controls operable by crew to required level of accuracy?


"Fly like you train...
Train like you fly..."

High Altitude ARNG Training Site

- Complex and varying terrain
- Slope Assessment
- 3D Wind
- Degraded Visual Environment (DVE)
  - White out/Brown Out
- Obstruction Identification

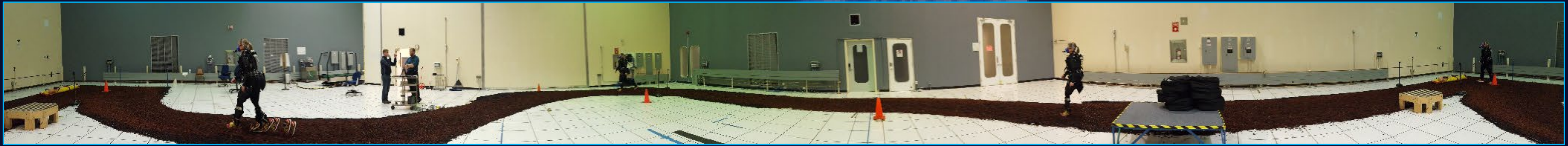
NASA Program of Instruction at HAATS

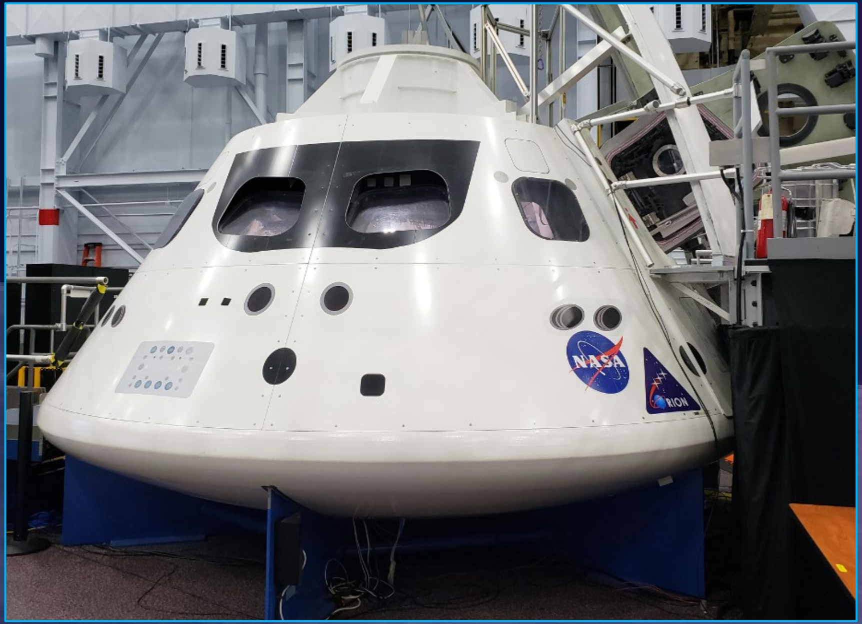
- Two week course; NLT L-18 month to flight
- Black Hawk Night Flight
  - White phosphor Night Vision Goggles (NVG)
- Chinook Autopilot Demo
  - Advanced auto land capability
  - Automation fails approaching LZ with large cliff requiring crew intervention

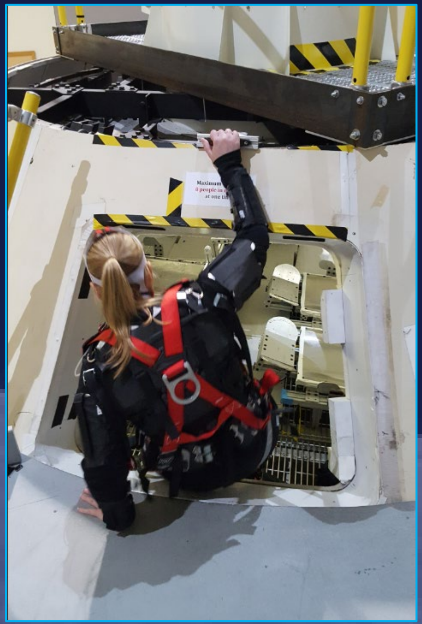
Human Factors

- Physiological understanding and limitations
- Human vulnerability to spatial disorientation
- Determination of spatial position, attitude, and motion
- Visual illusions and misinterpretations
- Proprioceptive-perception of body movement and positions
- Workload -Task Saturation & Spatial Disorientation
- Hypoxia exposure and management

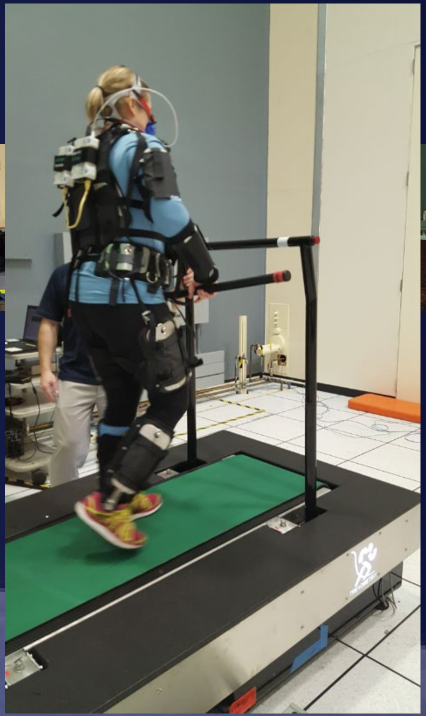
Fitness for Mission Tasks (FMT)







Fitness for Mission Tasks (FMT)



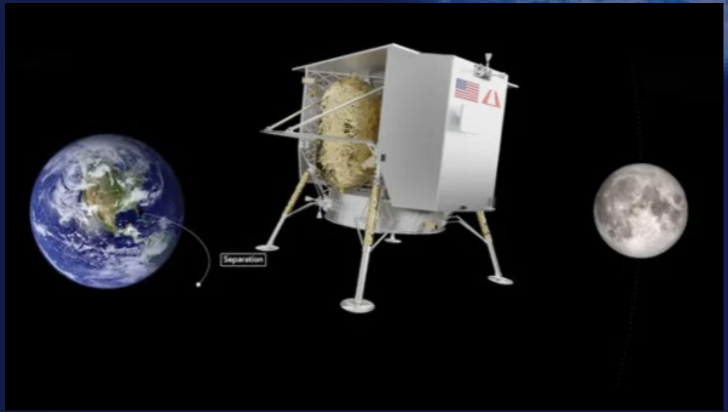
me snapped by Intuitive Machines' Odysseus lander on the surface of the moon on Feb. 22, 2024. The company shared this shot via X on Feb. 29, 2024, the day Odie powered down. (Image credit: Intuitive Machines)

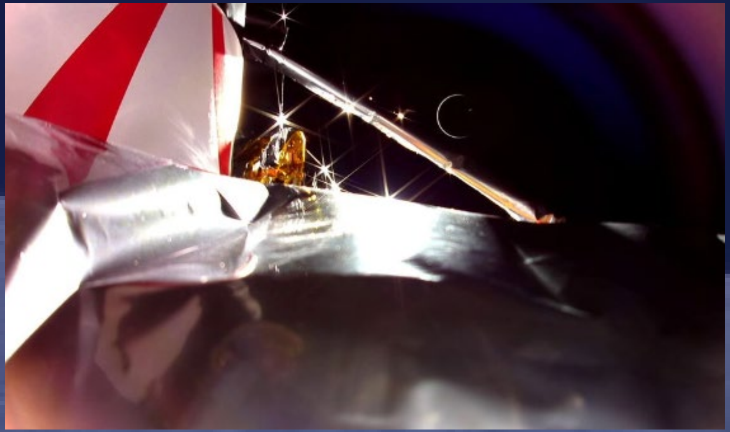
Rocket Science is Still Hard

JAXA SLIM
Sept 6, 2023 (Jan 19, 2024)

A camera aboard a small micro rover deployed from Japan's SLIM lunar lander captured an image of the probe resting on one side a few feet away after an engine malfunction during the final stages of descent Jan. 19. Image: JAXA.

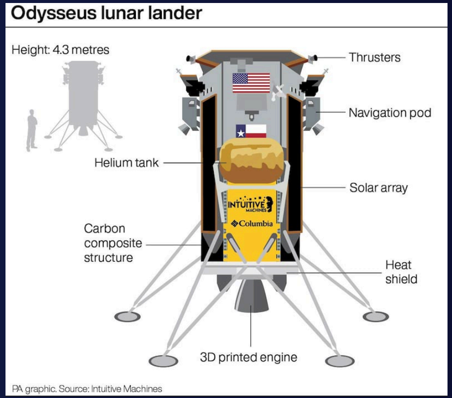
Astrobotic Peregrine Lander
Jan 8, 2024





A photograph of a crescent Earth seen by the Peregrine lander on Jan. 18 as it made its way toward a reentry over the Pacific. (Image credit: Astrobotic)

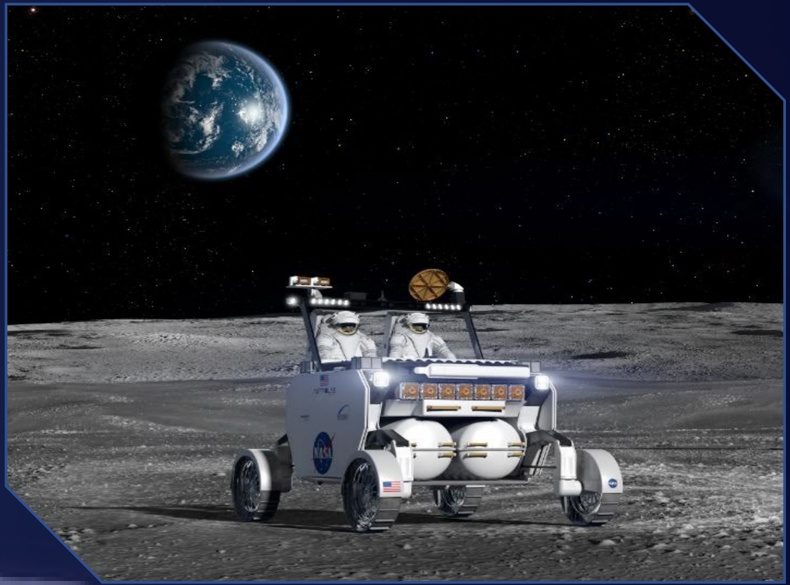
Intuitive Machines "Odie"
Feb 15, 2024 (Feb 22, 2024)



A selfie snapped by Intuitive Machines' Odysseus lander on the surface of the moon on Feb. 22, 2024. The company shared this shot via X on Feb. 29, 2024, the day Odie powered down. (Image credit: Intuitive Machines)

Lunar Surface Capabilities

NASA

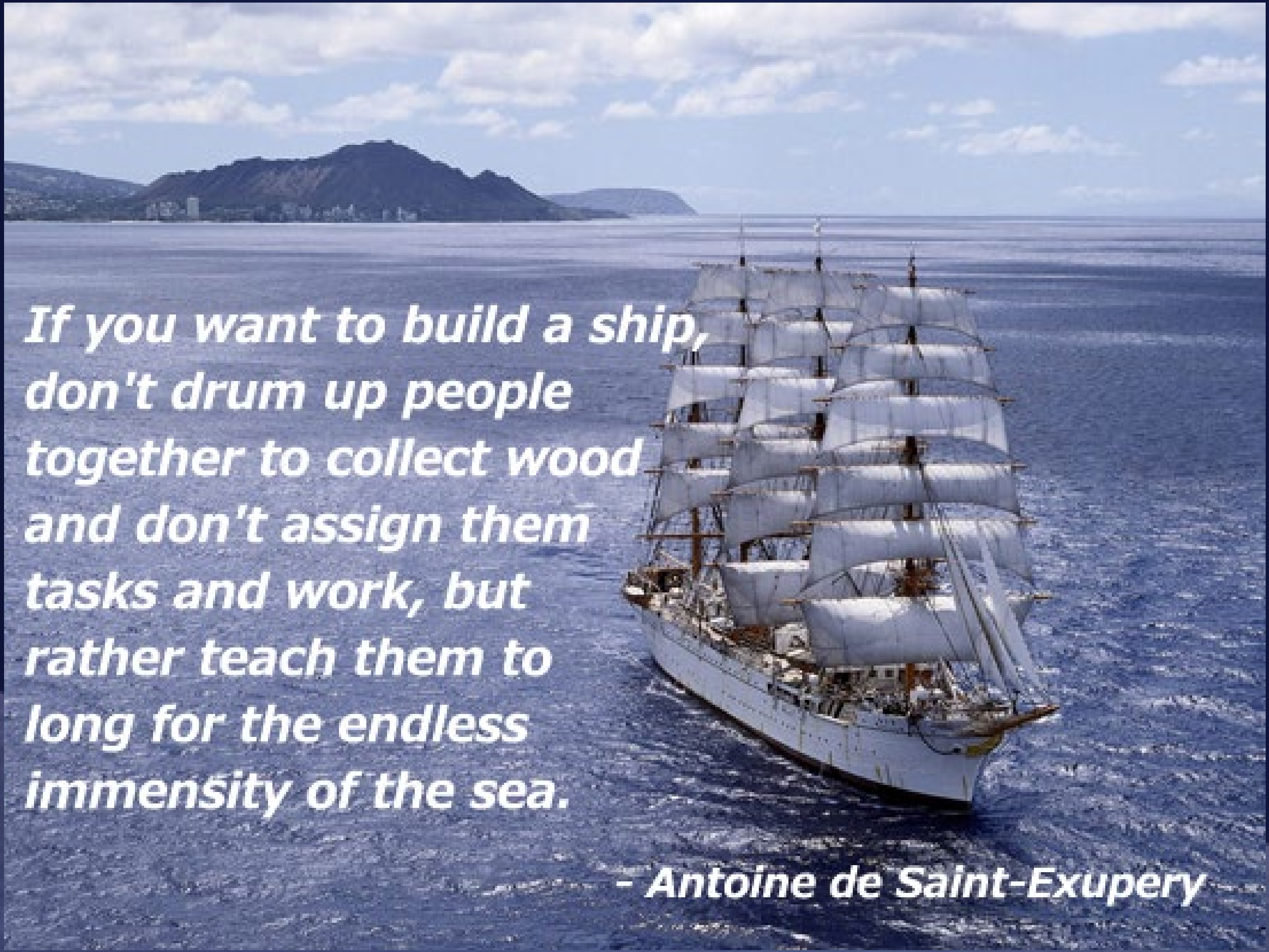


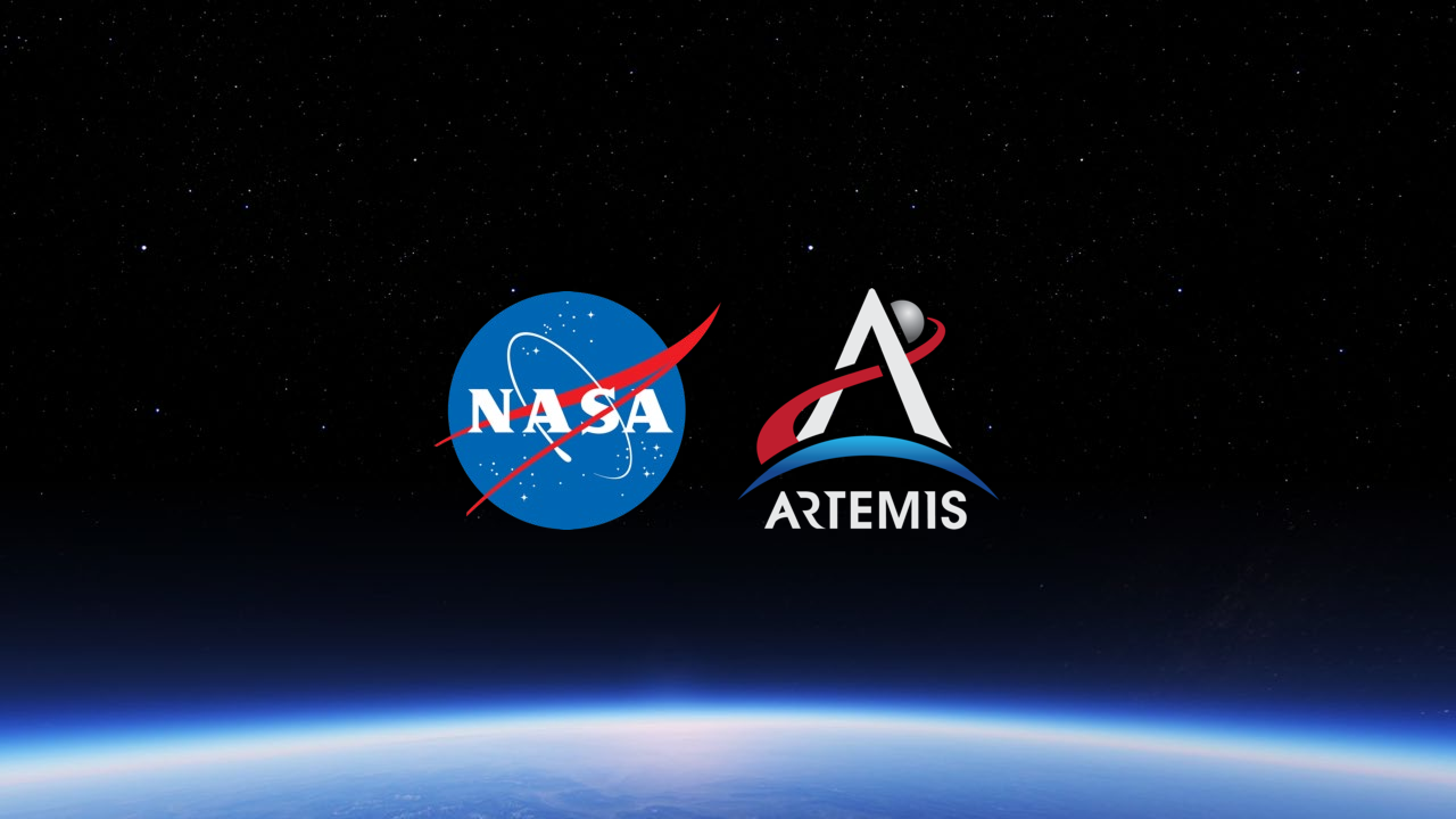
INTUITIVE MACHINES

Lunar Outpost™

ASTROLAB VENTURI

A Sustained Lunar Presence

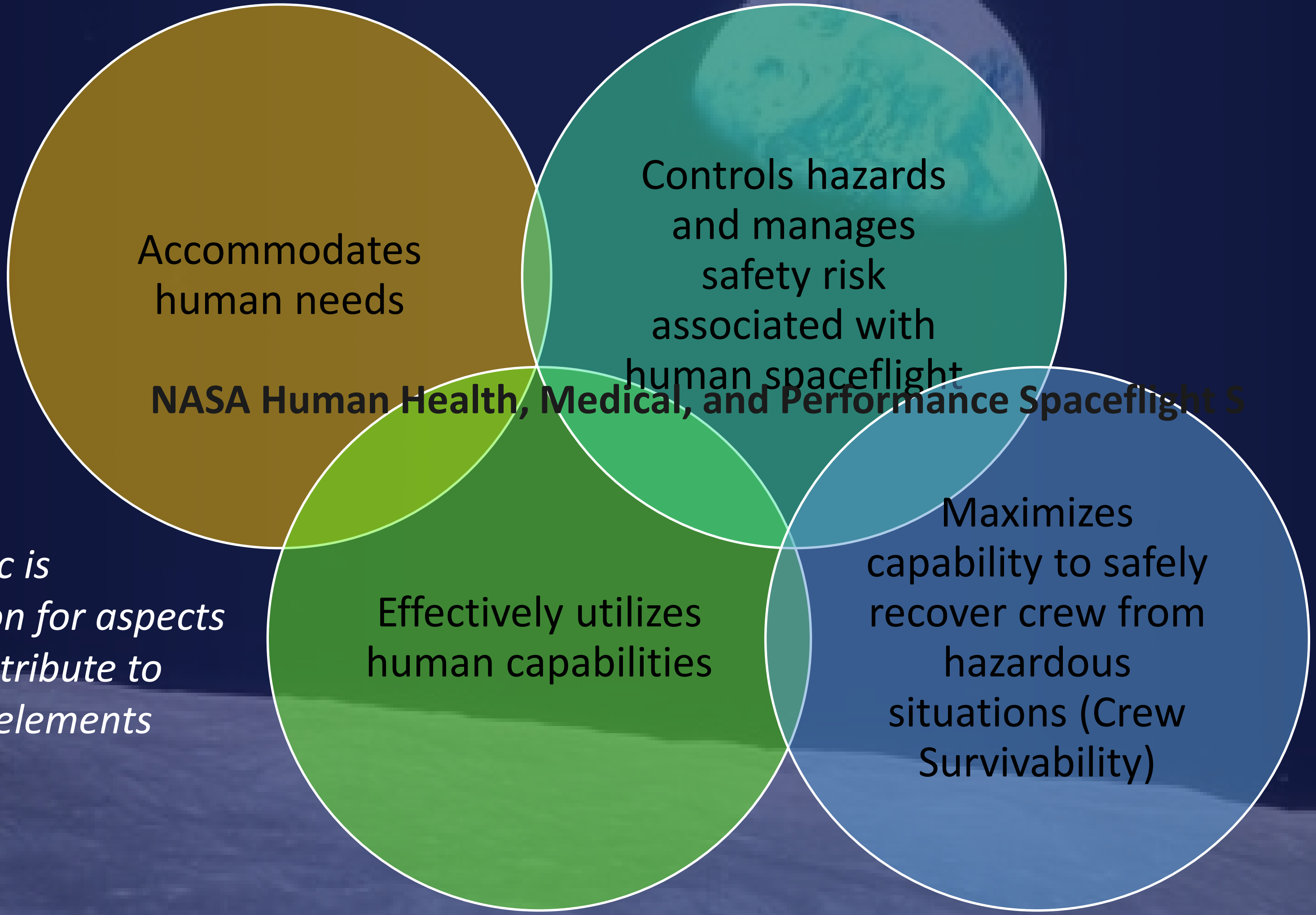

If you want to build a ship,
don't drum up people
together to collect wood
and don't assign them
tasks and work, but
rather teach them to
long for the endless
immensity of the sea.
- Antoine de Saint-Exupery


NASA
ARTEMIS

Backup

*Concept image

A Human-Rated System…



The overlapping graphic is intentional: it is common for aspects of vehicle design to contribute to multiple human rating elements

from the NASA Procedural Requirements for Human Rating (NPR 8705.2C)

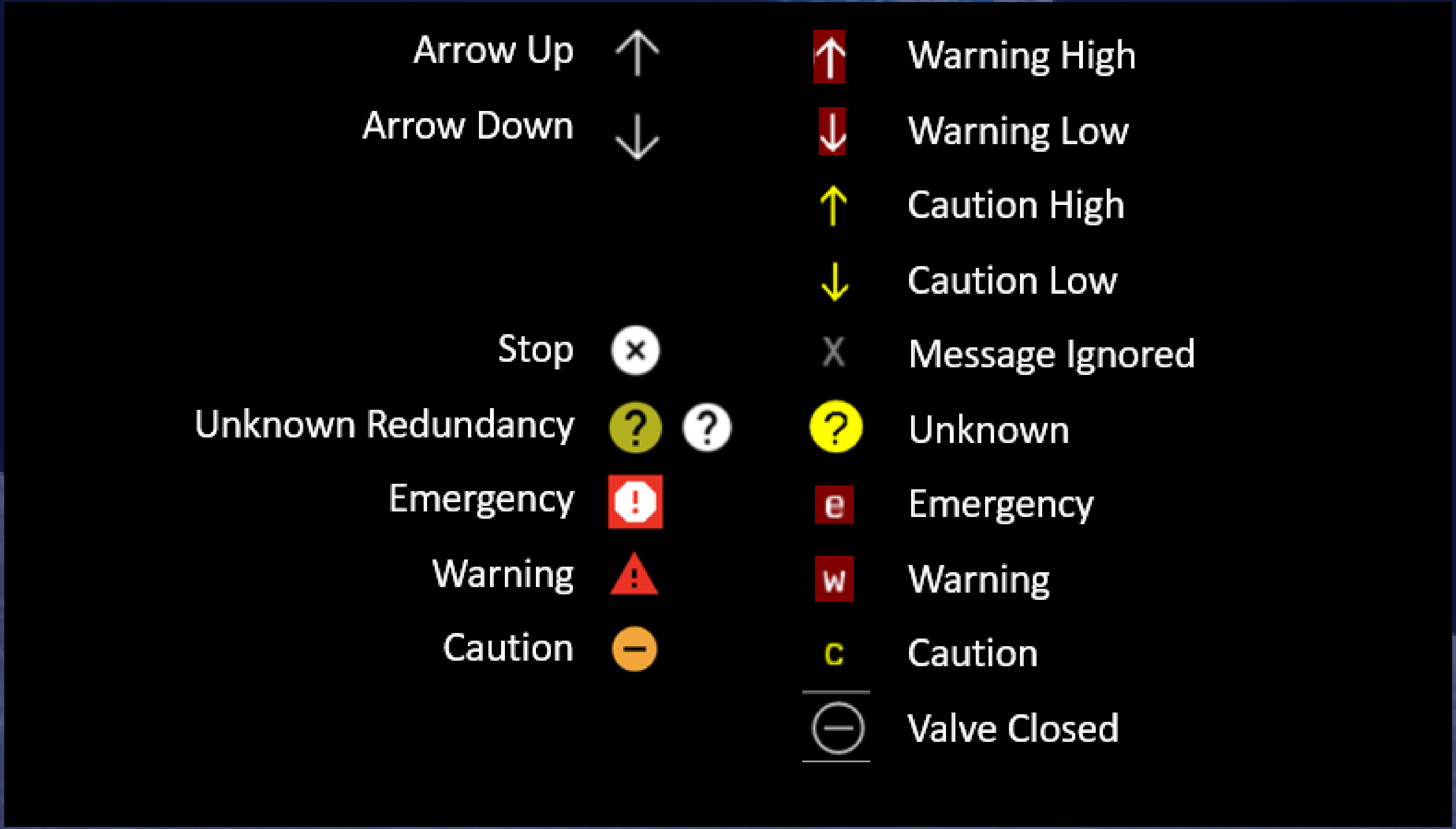
Virgin Galactic SpaceShip Two

- October 2014 catastrophic failure of SpaceShip Two (SS2) test flight resulted in death of co-pilot, serious injury of pilot, total destruction of SS2
- NTSB attributed caused to co-pilot error and failure of the spacecraft's developer to "**consider and protect against the possibility that a single human error could result in a catastrophic hazard** to the SpaceShipTwo vehicle"
  - Co-pilot committed error of unlocking SS2's novel tail-boom "feathering" system too early while flying at Mach 0.8 rather than Mach 1.4, as original flight plan required
  - Early engagement of feathering system rotated twin tail booms upward while rocket motor was still firing during re-entry boost phase
  - Turbulence during the plane's transonic flight overpowered the tail booms' securing mechanism, leading to the vehicle's destruction
- NTSB determined error committed by **veteran test pilot** due to lack of **consideration for human error** compounded by **task stressors**
  - Hazard analysis did not consider pilot-induced hazards
  - System not designed with safeguards to prevent unlocking feather
  - Manuals/procedures did not have warning about unlocking feather early
  - Simulator training did not fully replicate operational environment
  - Task time was a stressor – had to be completed within 26 seconds or abort at 1.8 Mach if feather not unlocked
  - Task memorization was a stressor – flight test data card not used
  - Operational environment was a stressor – pilots had not previously experienced SS2 vibration and loads

Consistent Icon and Symbology

Example Vehicle Display #1

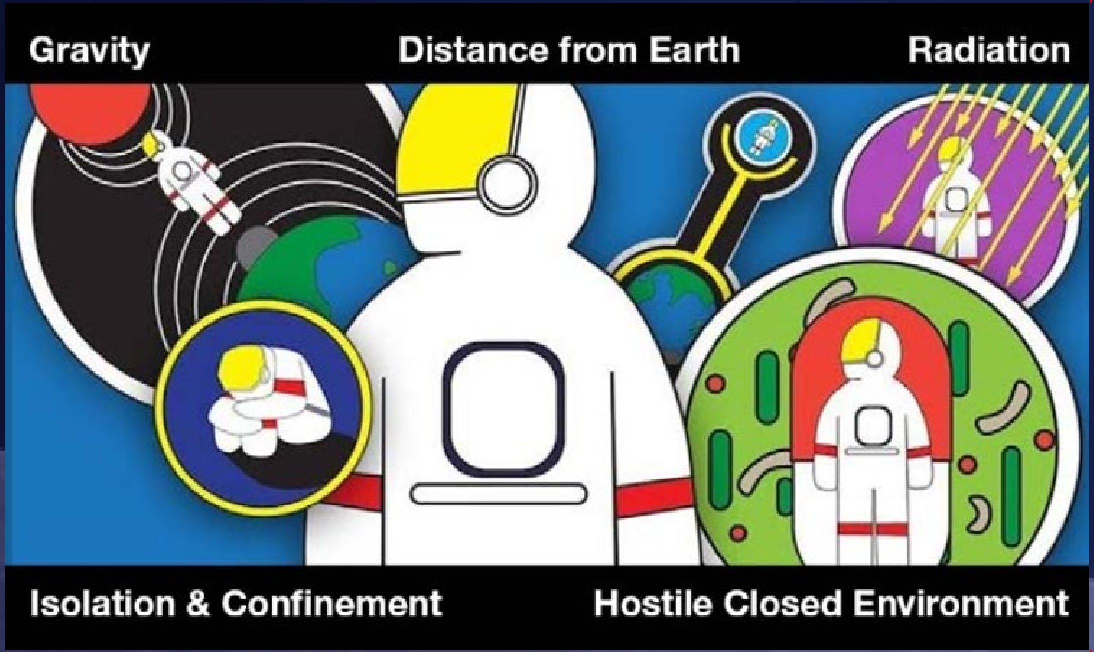
Example Vehicle Display #2

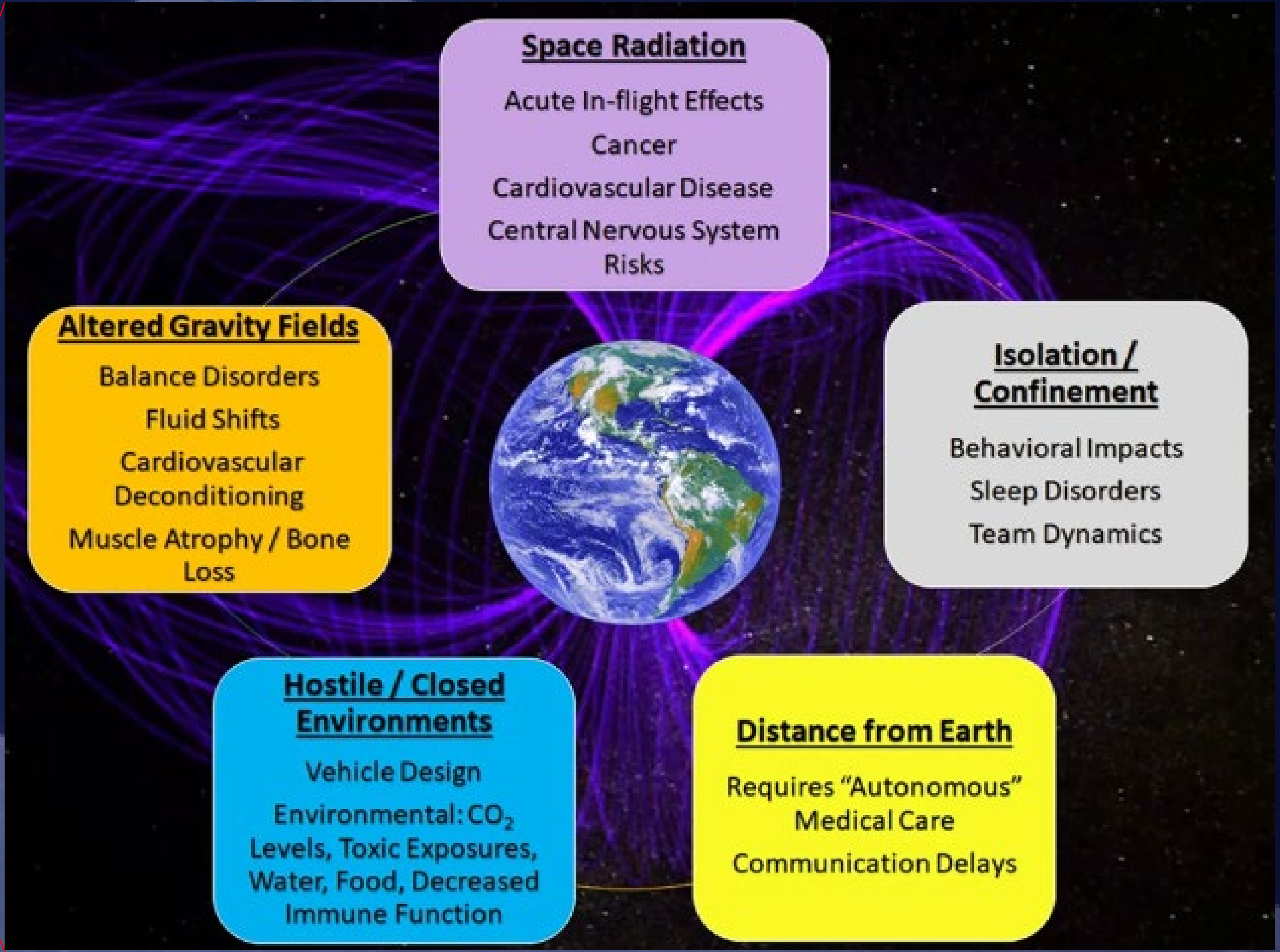


Opportunities in Human Spaceflight Careers

- USAJOBS - The Federal Government's official employment site
- https://spacemedicineassociation.org/
- https://www.asma.org

Human Risks in Extreme Environments





The NASA Workforce

- DEIA talking points
- Best place to work in the government for XX years running
- Our people are our greatest asset