# Future of NASA Exploration of Air and Space

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University of Cincinnati
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# What Does NASA Do?

## Aeronautics Research

Transform Aviation through R&D

## Space Operations

Launch and Space Operations

## Deep Space Exploration Sys.

Moon to Mars Exploration

## Science

Understand the Sun, Earth, and Universe

## Space Technology

Develop and transfer revolutionary technologies

# NASA Centers




Ames Research Center

Glenn Research Center

HQ

Goddard Space Flight Center

Langley Research Center

Marshall Space Flight Center

Armstrong Flight Research Center

Jet Propulsion Laboratory



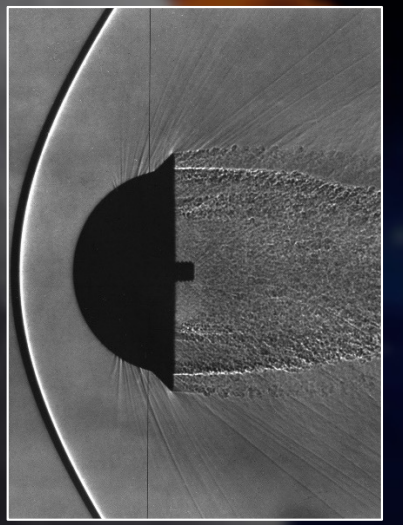
Johnson Space Center

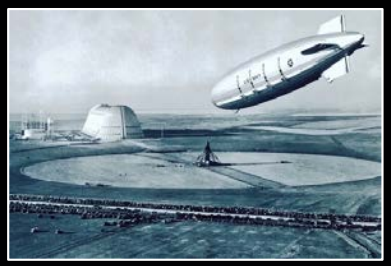
Stennis Space Center

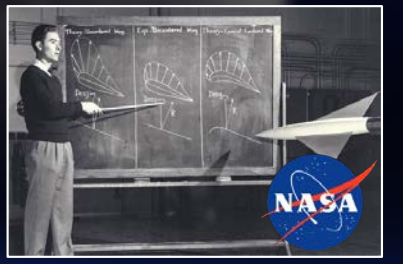
Kennedy Space Center

# Ames Aeronautical Laboratory

## NACA's Second Laboratory




1915 1917 1939 1941 1946 1958

"Langley Memorial Aeronautical Laboratory"
Langley Research Center (LaRC)

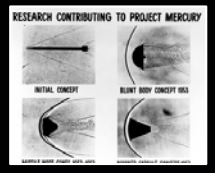
**"Ames Aeronautical Laboratory"**
**Ames Research Center (ARC)**

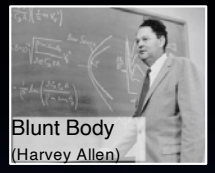
"Aircraft Engine Research Laboratory"
Glenn Research Center (GRC)

"Muroc Flight Test Unit"
Armstrong Flight Research Center (AFRC)

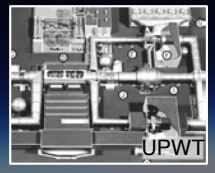
# 83 Years of Innovation











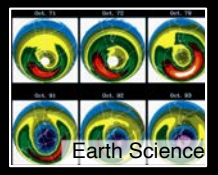
1940 2020

# 83 Years of Innovation

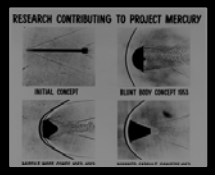




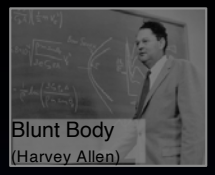






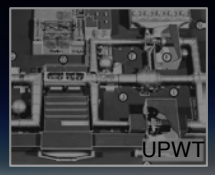


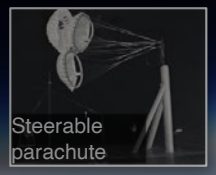


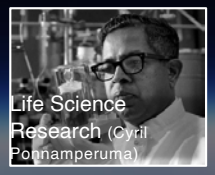








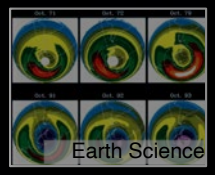



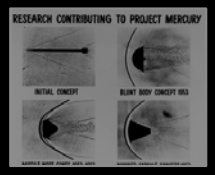


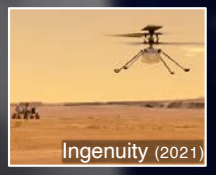
1940 2020

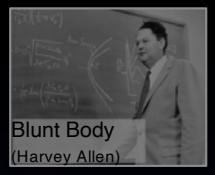
# 83 Years of Innovation

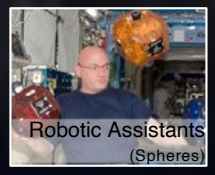


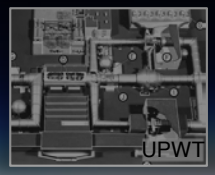


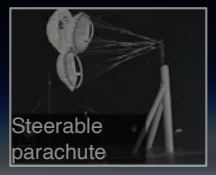


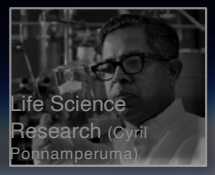



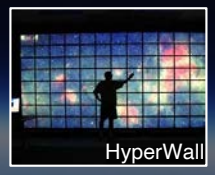


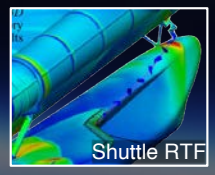













1940 2020

# Ames Today

## Occupants

- *~1,300 civil servants*
- *~1,900 on-site contractors*
- *~2,400 NRP workforce*
- *~700 summer students in 2019*

## FY21 Budget

- *~$1B (includes reimbursable/EUL)*

## Real Property

- *~1,100 acres*
- *400 acres security perimeter*
- *5M building ft$^2$*
- *Airfield with ~9,000 and 8,000 ft. runways*

# Ames Today (NASA Research Park)

## Occupants

- *~1,300 civil servants*
- *~1,900 on-site contractors*
- *~2,400 NRP workforce*
- *~700 summer students in 2019*

## FY21 Budget

- *~$1B (includes reimbursable/EUL)*

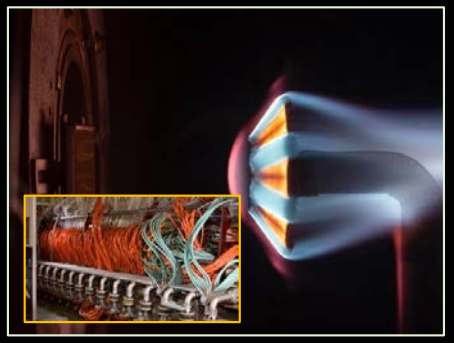
## Real Property

- *~1,100 acres*
- *400 acres security perimeter*
- *5M building ft$^2$*
- *Airfield with ~9,000 and 8,000 ft. runways*

# Core Competencies

Air Traffic Management

Entry Systems



Advanced Computing & IT

Intelligent / Adaptive Systems

Cost-Effective Space Missions

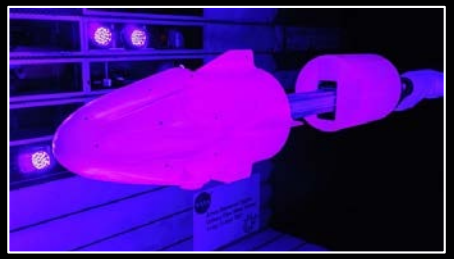
Aerosciences

Astrobiology & Life Science

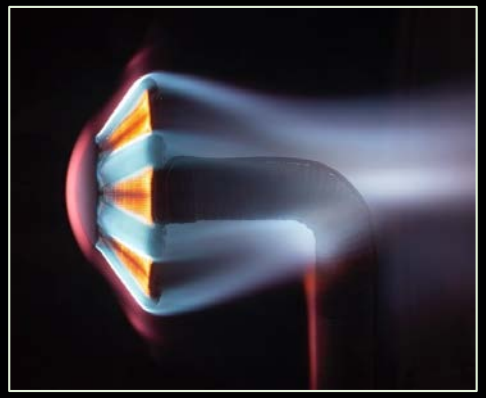
Space & Earth Sciences

# Major Research Facilities

## Wind Tunnels

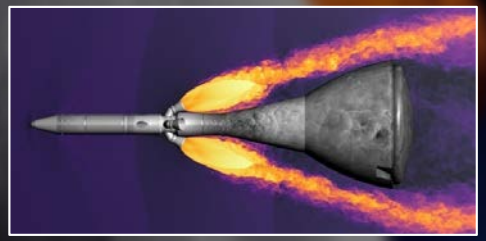


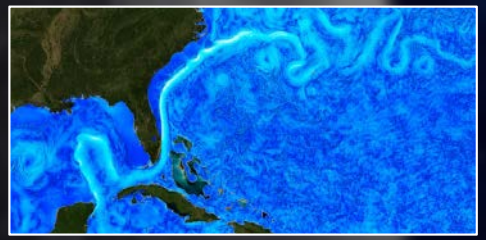
## Arc Jet Complex



## Simulators

## Supercomputing





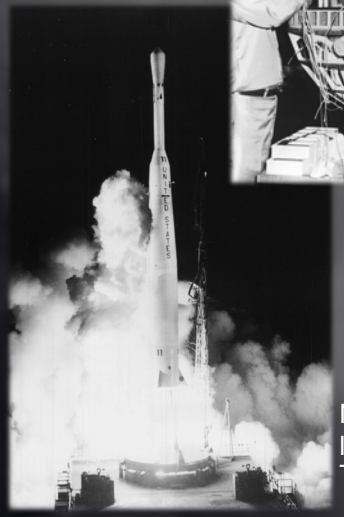
# 119 Years Since “Kitty Hawk”


Ford Trimotor (1925)

X-1A (1946)

DC-3 (1935)

X-2 (1952)



NASA launched AT&T Telstar (1962)


Kitty Hawk (1903)

Boeing 247 (1934)

X-15 (1959)

Space

Aviation

NACA (1915)

FAA, NASA (1958)

Civil Aeronautics Act (1938)

Airline Deregulation Act (1978)

Air Commerce Act (1926)

The Air Mail Act (1925)



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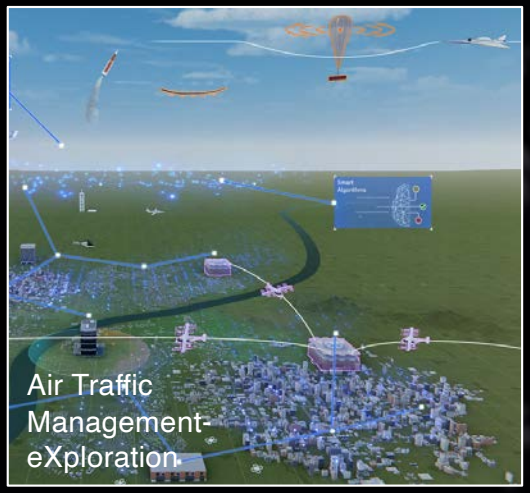
# Aeronautics Research

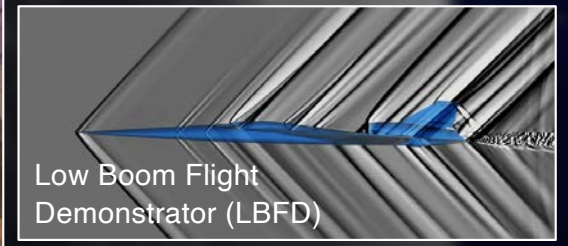
*Transform aviation through revolutionary technology research, development, and transfer*

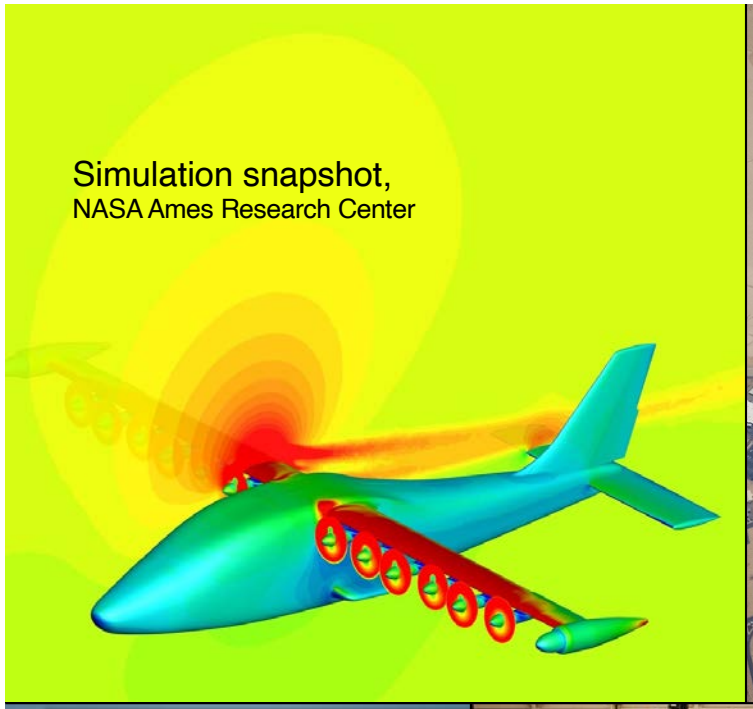





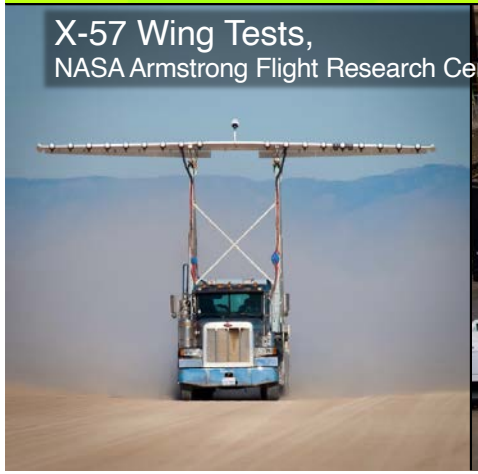


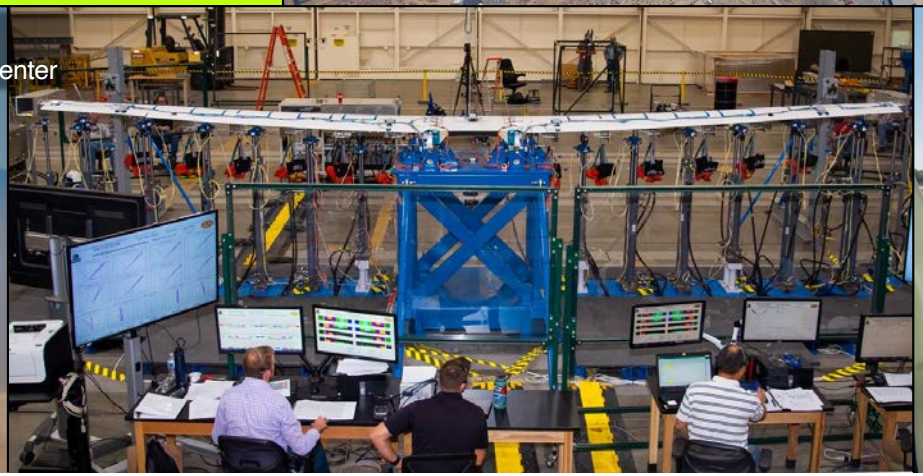






Simulation snapshot,
NASA Ames Research Center


All-Electric X-57 Maxwell
N857NA
NASA

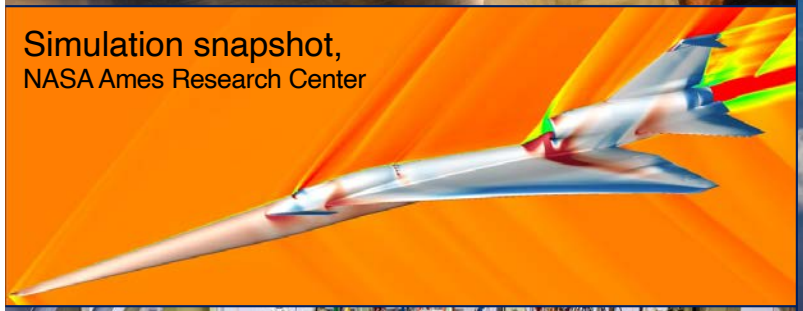

X-57 Wing Tests,
NASA Armstrong Flight Research Center




Tecnam P2006T cockpit

# X-59 Low Boom Flight Demonstrator

Wind Tunnel Tests,
NASA Ames Research Center

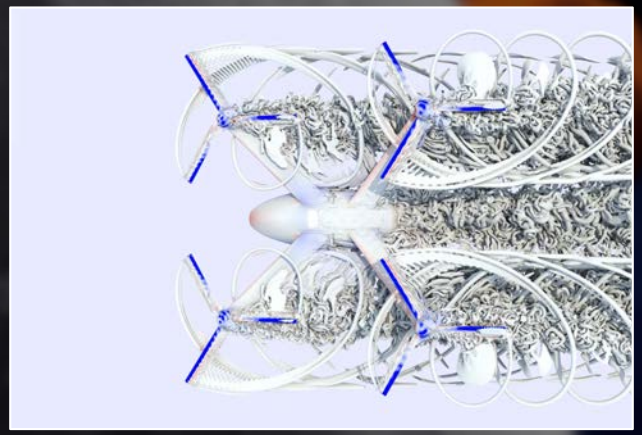


Simulation snapshot,
NASA Ames Research Center

Final Integration
Lockheed Martin's *Skunk Works*, Palmdale, CA

Aeronautics Research

# *Advanced Air Mobility*



# Exploration Systems Development

*Define and manage systems development for programs critical to Artemis and plan the Moon to Mars exploration approach in an integrated manner*

Orion Space Craft

Space Launch System

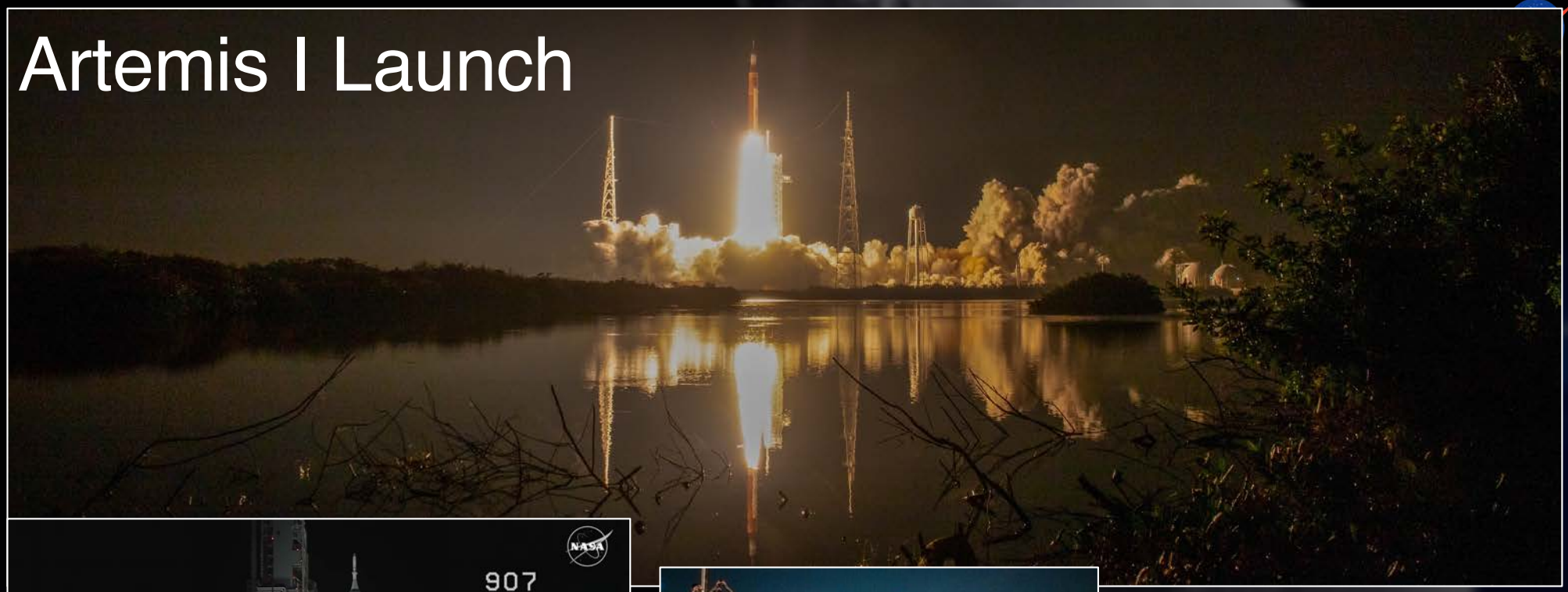
Exploration Ground Systems

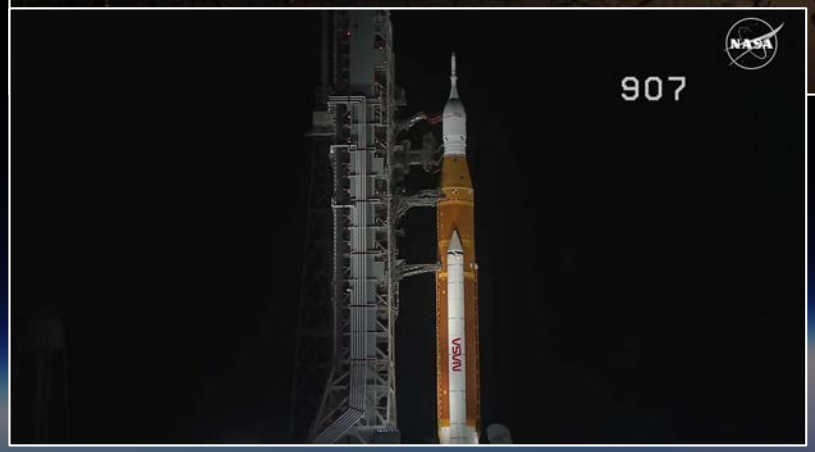
Gateway

Human Landing System

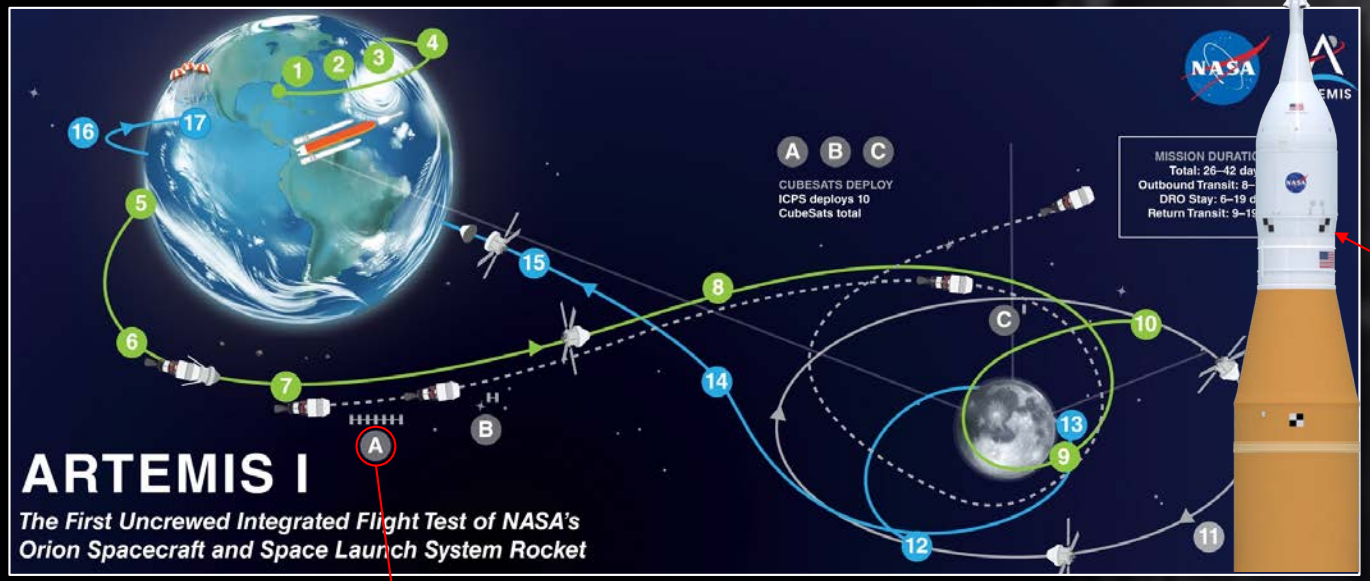
Artemis Base Camp

# Artemis I Launch



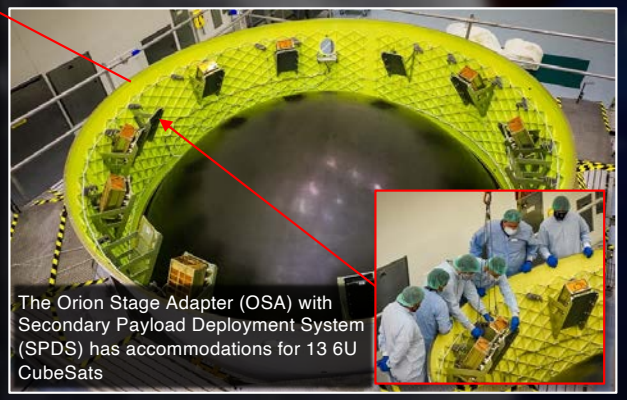


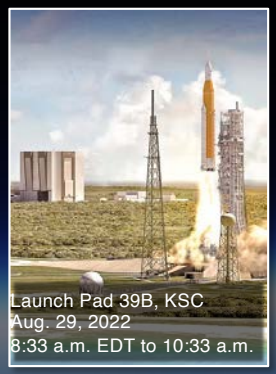

# Artemis I Mission

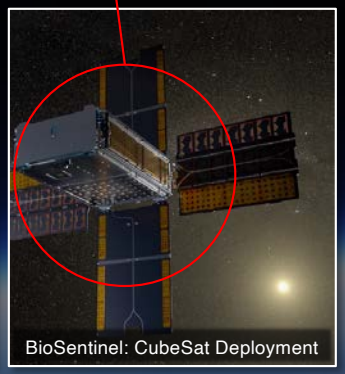




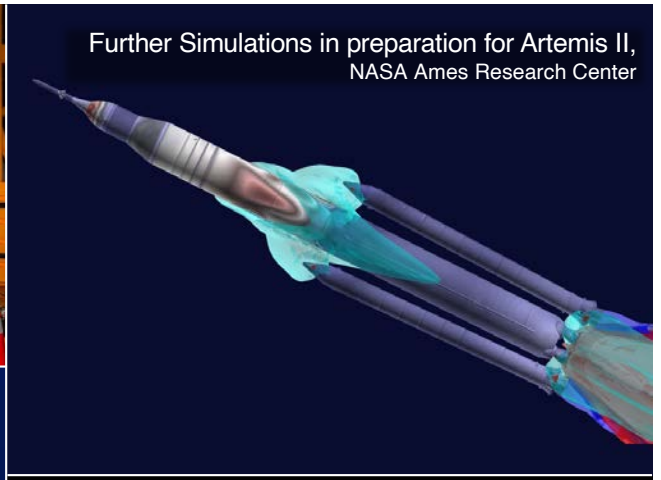
BioSentinel Deployment Simulation


The Orion Stage Adapter (OSA) with Secondary Payload Deployment System (SPDS) has accommodations for 13 6U CubeSats


Launch Pad 39B, KSC
Aug. 29, 2022
8:33 a.m. EDT to 10:33 a.m.


BioSentinel: CubeSat Deployment


"Rehersal" @ MMOC, NASA Ames

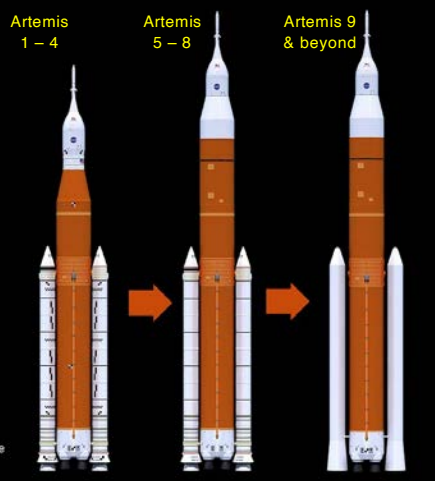


| | | | |
|---|---|---|---|
| Payload to TLI/Moon | > 26 t (57k lbs) | 34–37 t (74k–81k lbs) | > 45 t (99k lbs) |
| Payload Volume | N/A** | 10,100 ft³ (286m³)** | 10,100 ft³ (286m³)** |

**Trans-Lunar Injection (TLI)** is a propulsive maneuver used to set a spacecraft on a trajectory that will cause it to arrive at the Moon. A spacecraft performs **TLI** to begin a lunar transfer from a low circular parking orbit around Earth.

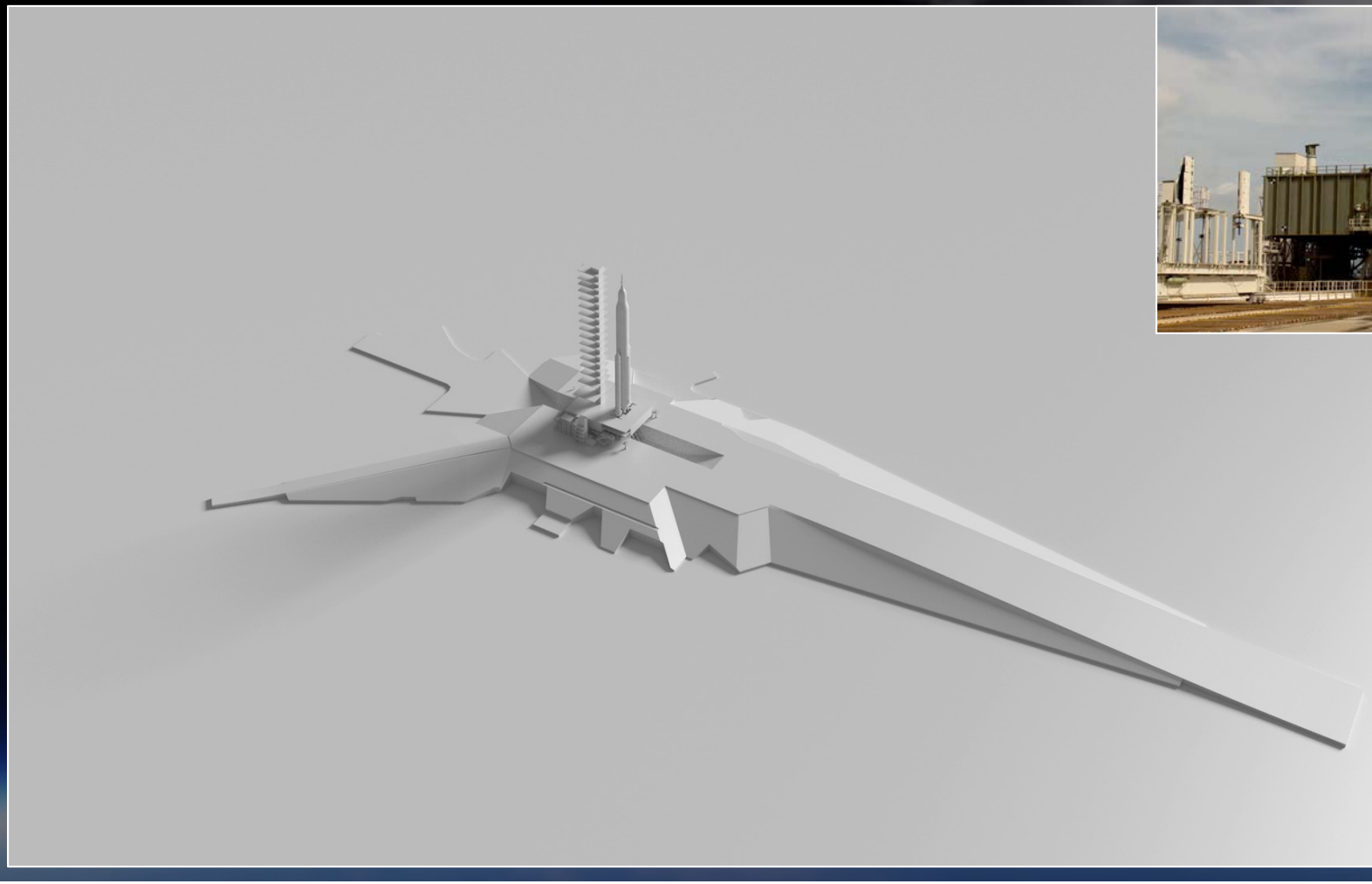
The numbers depicted here indicate the mass capability at the Trans-Lunar Injection point.

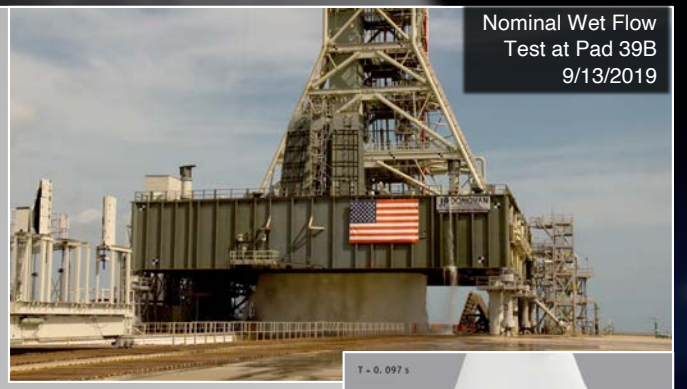
** Not including Orion/Service Module volume




| | | | |
|---|---|---|---|
| Maximum Thrust | 8.8M lbs | 8.8M lbs | 11.9M lbs |

# Launch Environment Simulation





Nominal Wet Flow Test at Pad 39B 9/13/2019


SLS's RS-25 rocket & SRB plume-water interaction simulation

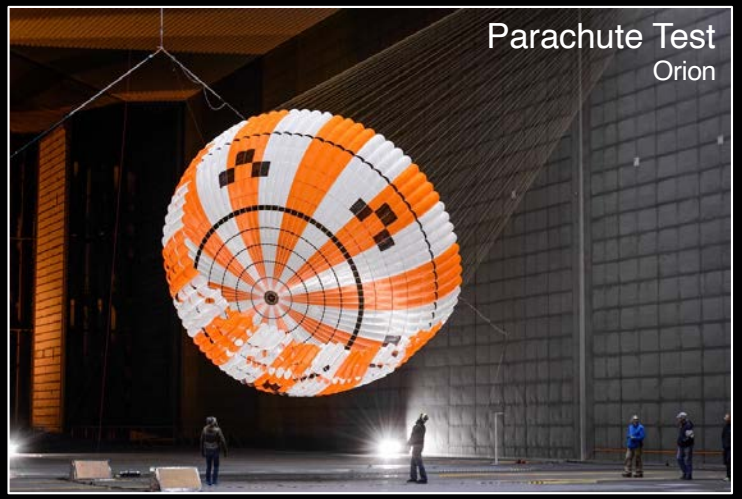
# *Artemis I Launch: Stage Separation Simulation*

SRB Separation
Space Launch Vehicle

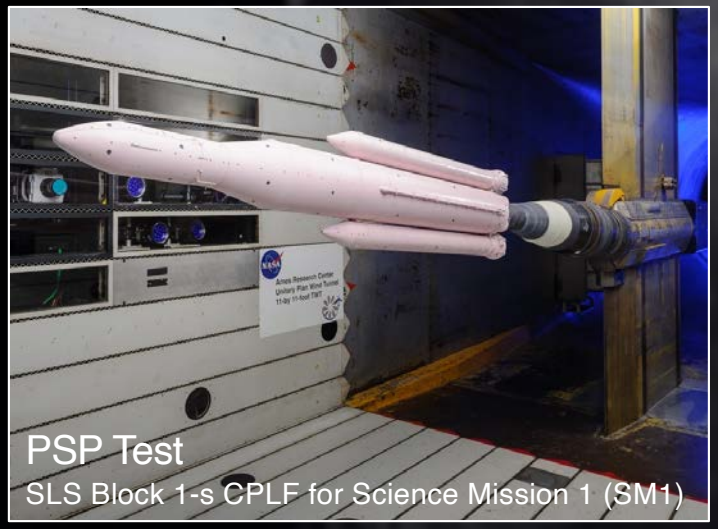
*Particle traces colored in time during SLS Stage Separation even*

Exploration Systems Development

# *Wind Tunnel Testing*



Parachute Test
Orion



PSP Test
SLS Block 1-s CPLF for Science Mission 1 (SM1)

Hot Helium Testing
Orion

Wind Tunnel Model and Instrumentation
SLS Block 1B

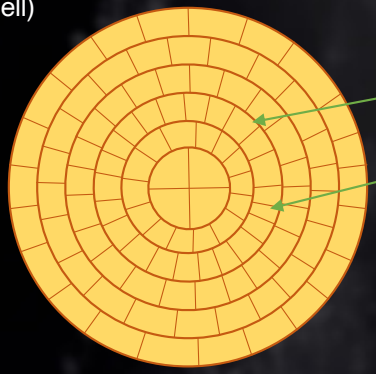
Pressure Sensitive Paint Test
Space Launch System

Exploration Systems Development

# *Heatshield and Backshell Development*

Orion 3DMAT Material Response in IHF/LEAF for combined convective and radiative test

Artemis 1&2 Instrumentation Hardware (Heatshield And Backshell)



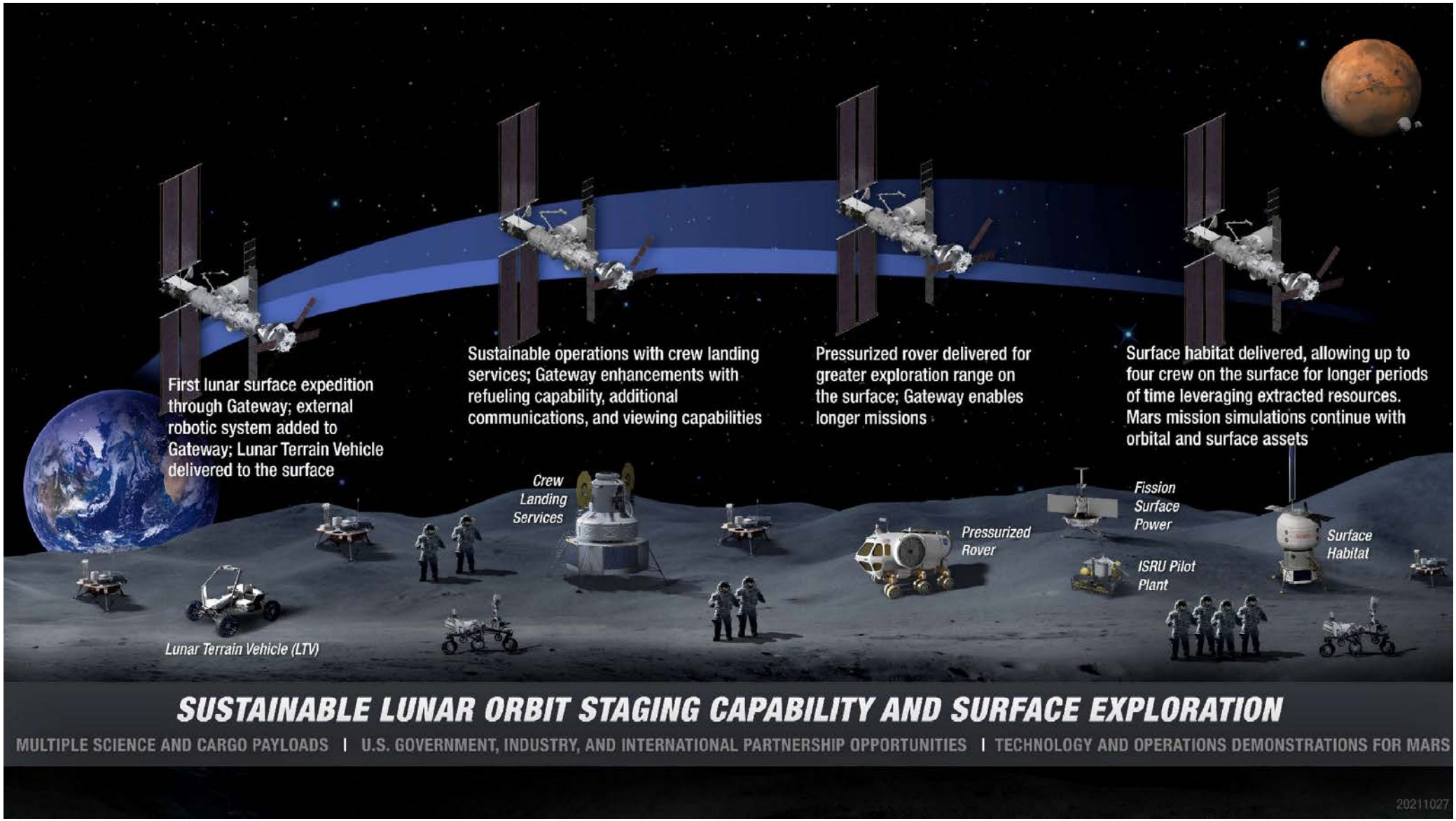
DFI Sensors
Artemis-1

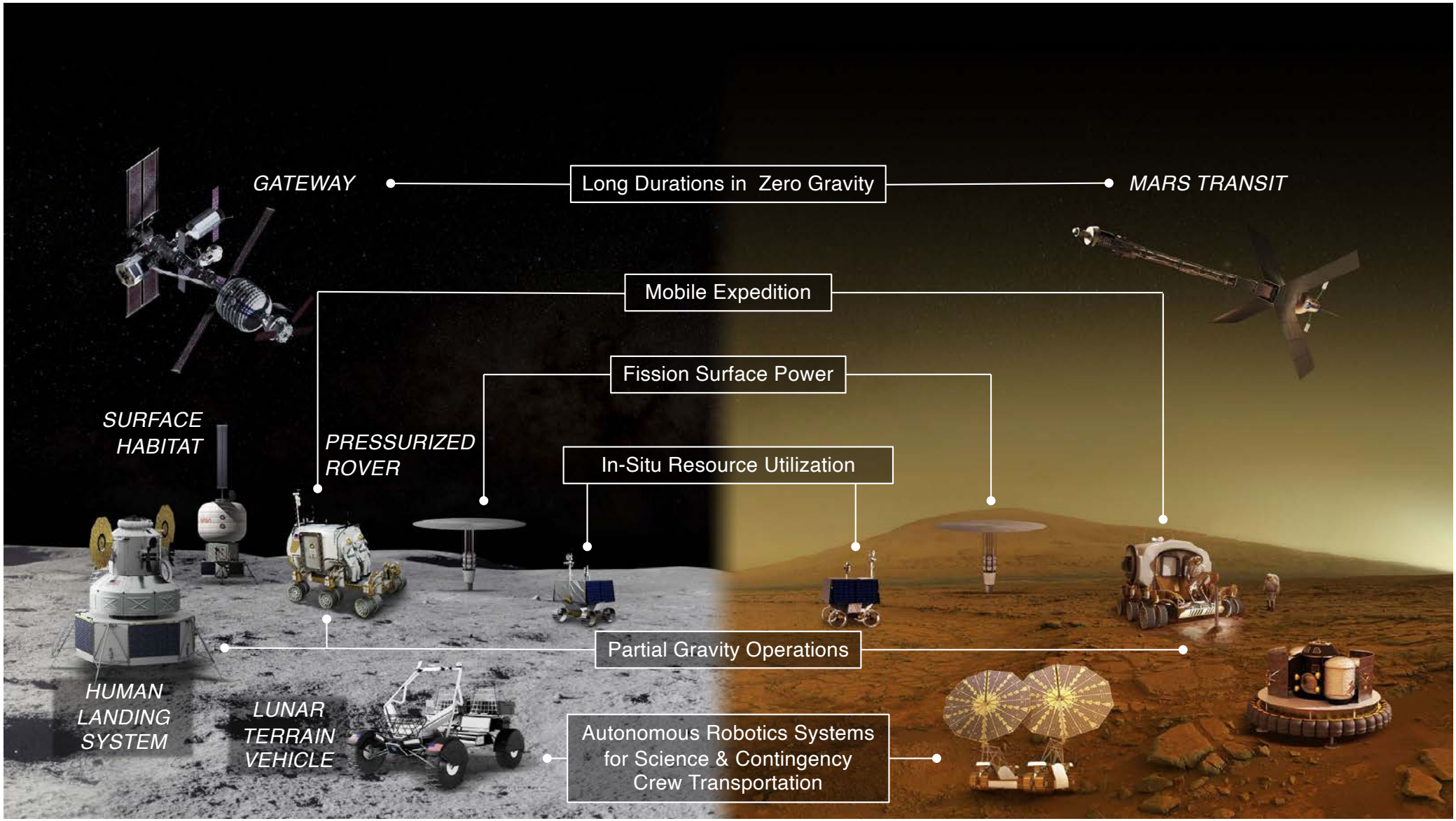
Thermocouple plug

Radiometer sub-assembly prior to installation into heat shield

Orion heatshield material exposed to arcjet plasma

Engineers from Ames Research Center and Marshall Space Flight Center remove Avcoat segments from the surface of the Orion heat shield.


First lunar surface expedition through Gateway; external robotic system added to Gateway; Lunar Terrain Vehicle delivered to the surface
Sustainable operations with crew landing services; Gateway enhancements with refueling capability, additional communications, and viewing capabilities
Pressurized rover delivered for greater exploration range on the surface; Gateway enables longer missions
Surface habitat delivered, allowing up to four crew on the surface for longer periods of time leveraging extracted resources. Mars mission simulations continue with orbital and surface assets
Crew Landing Services
Pressurized Rover
Fission Surface Power
ISRU Pilot Plant
Surface Habitat
Lunar Terrain Vehicle (LTV)
SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION
MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS
20211027


GATEWAY
Long Durations in Zero Gravity
MARS TRANSIT
Mobile Expedition
Fission Surface Power
SURFACE HABITAT
PRESSURIZED ROVER
In-Situ Resource Utilization
Partial Gravity Operations
HUMAN LANDING SYSTEM
LUNAR TERRAIN VEHICLE
Autonomous Robotics Systems for Science & Contingency Crew Transportation

# VIPER Surface Segment (Rover + Instruments)

**Subsurface excavation**
TRIDENT Drill

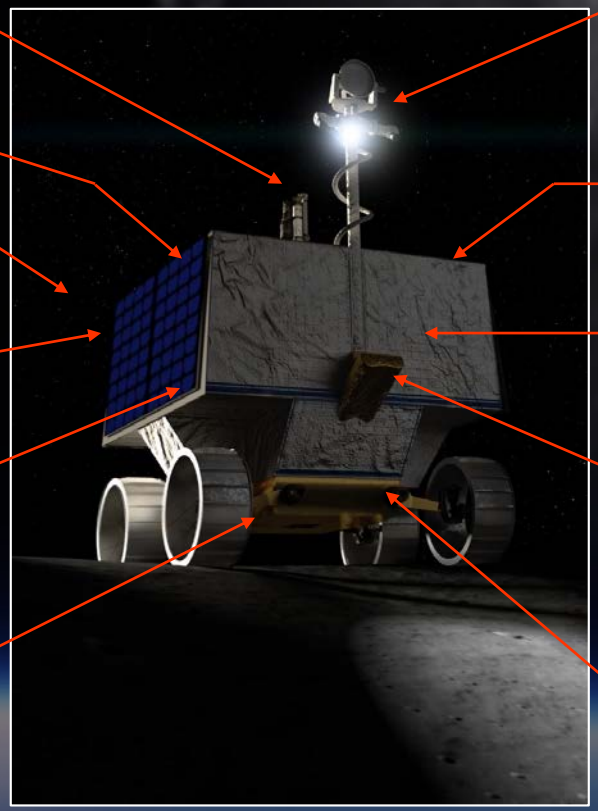
**Localization**
Star tracker

**Situational Awareness**
Aft Cams (1pr)

**Situational Awareness**
Hazard Cams
(2 cams x 2 sides)

**Power**
Solar Array (3-sides)

**Prospecting & Evaluation**
Mass Spectrometer Observing Lunar Operations (MSolo) Instrument



**Situational Awareness & Communication**
Nav Cams (1pr)
Lights (1pr)
Antenna Mast

**Heat Rejection**
Radiator (on top)

**Rover Control**
Flight Avionics (internal)

**Prospecting**
Neutron Spectrometer System (NSS) Instrument

**Prospecting & Evaluation**
Near Infrared Volatiles Spectrometer System (NIRVSS) Instrument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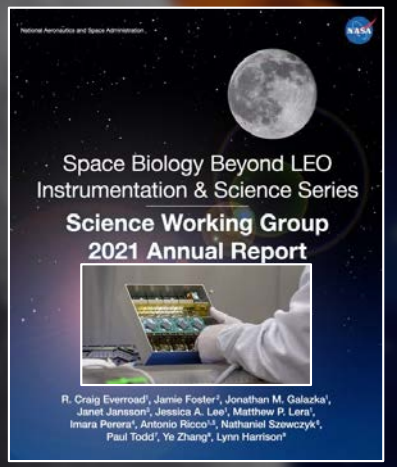
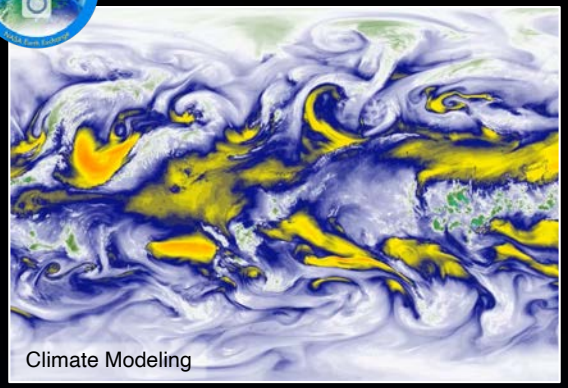
# Science

*Understand the Sun, Earth, Solar System, and Universe*





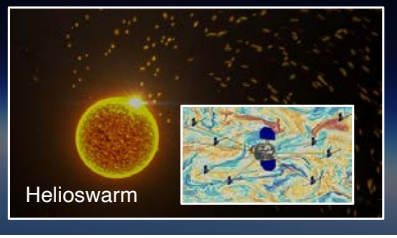










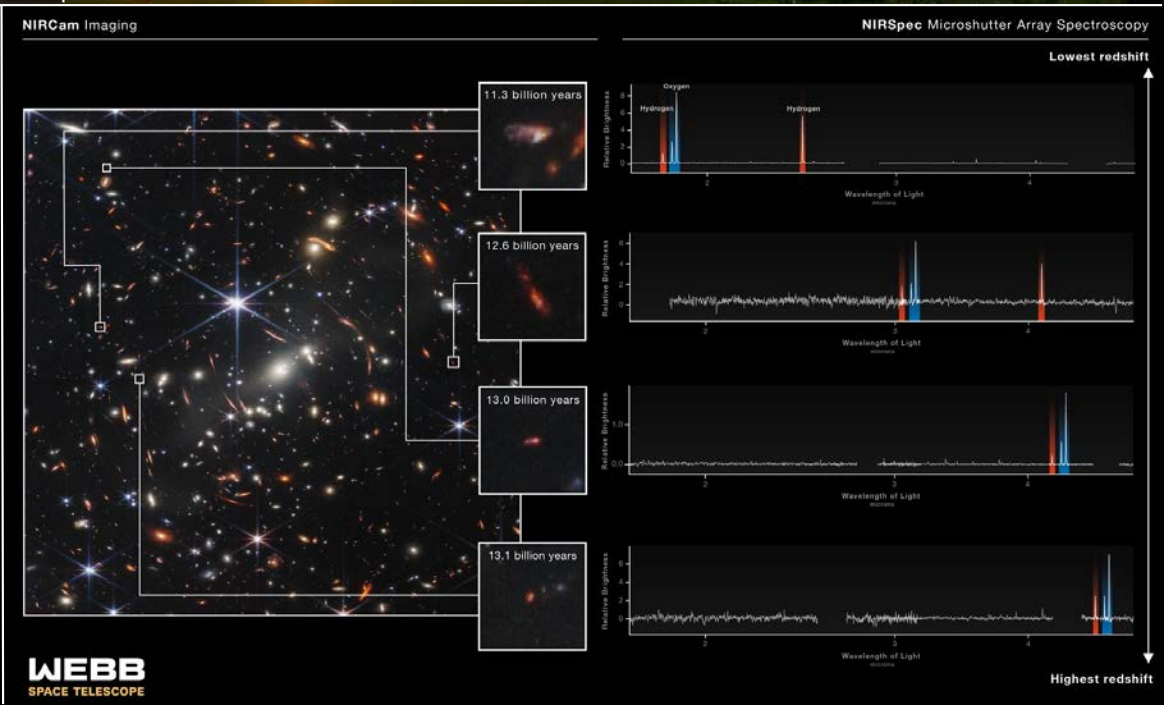



Hubble: Visible

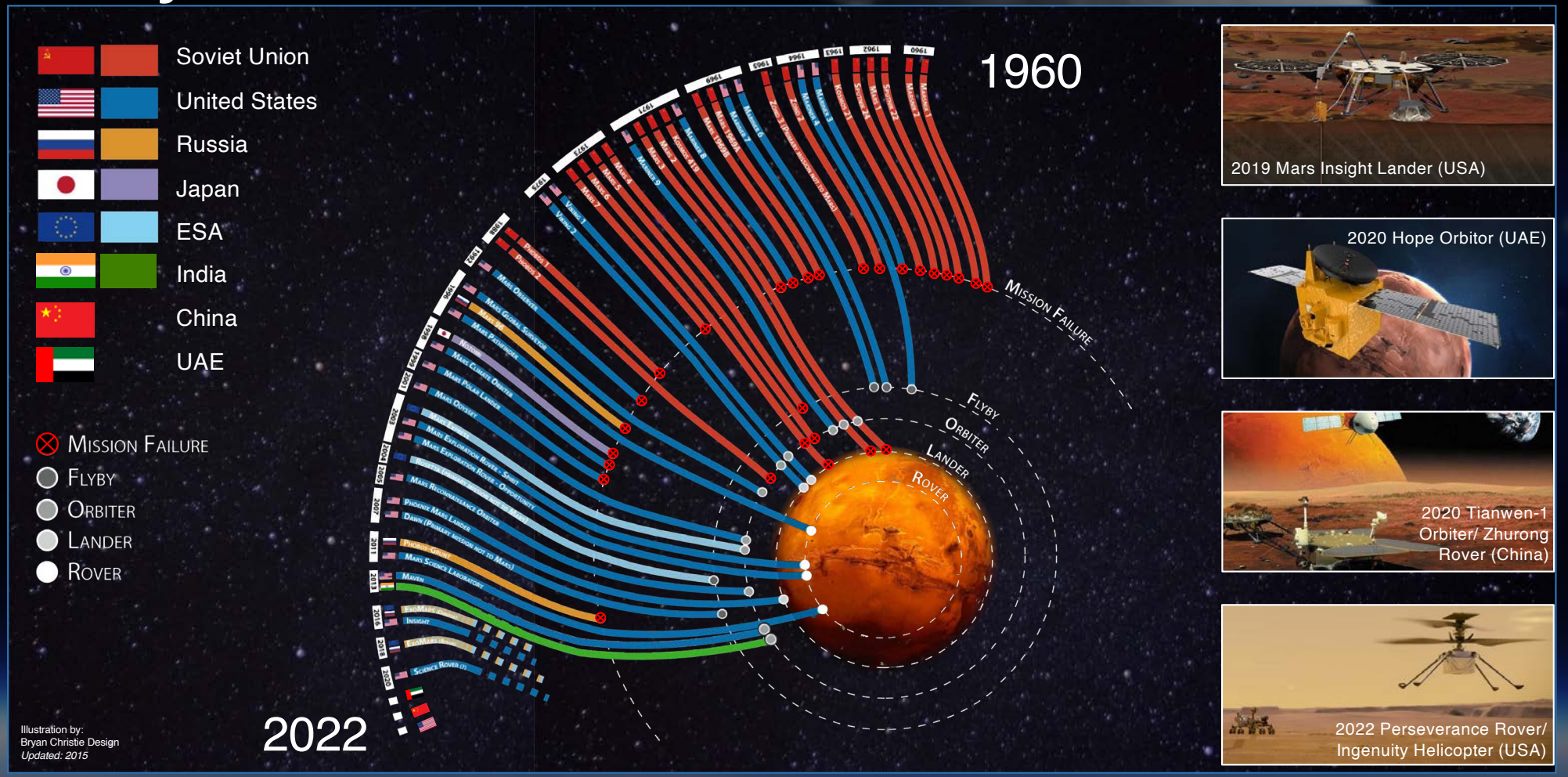

JWST: Near-infrared


JWST: mid-infrared


esa
ariane


NIRCam Imaging
NIRSpec Microshutter Array Spectroscopy
Lowest redshift
11.3 billion years
12.6 billion years
13.0 billion years
13.1 billion years
Oxygen
Hydrogen
Hydrogen
Relative Brightness
Wavelength of Light
WEBB
SPACE TELESCOPE
Highest redshift

# Sixty Years of Mars Missions



# MARS Perseverance Rover and Ingenuity Helicopter


Testing a Parachute Made for Mars

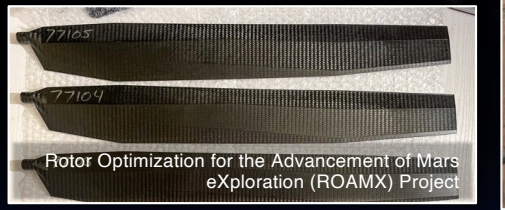

July 30, 2020

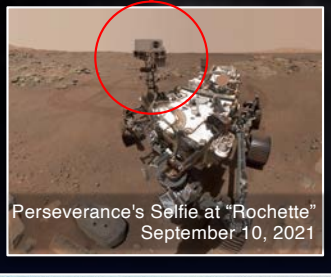


Shielding the Spacecraft During Its Fiery Descent


Feb 18, 2021


Measuring the Extreme Environment During Landing


Rotor Optimization for the Advancement of Mars eXploration (ROAMX) Project


Perseverance's Selfie at "Rochette" September 10, 2021


Solar Eclipse on Mars April 20, 2022

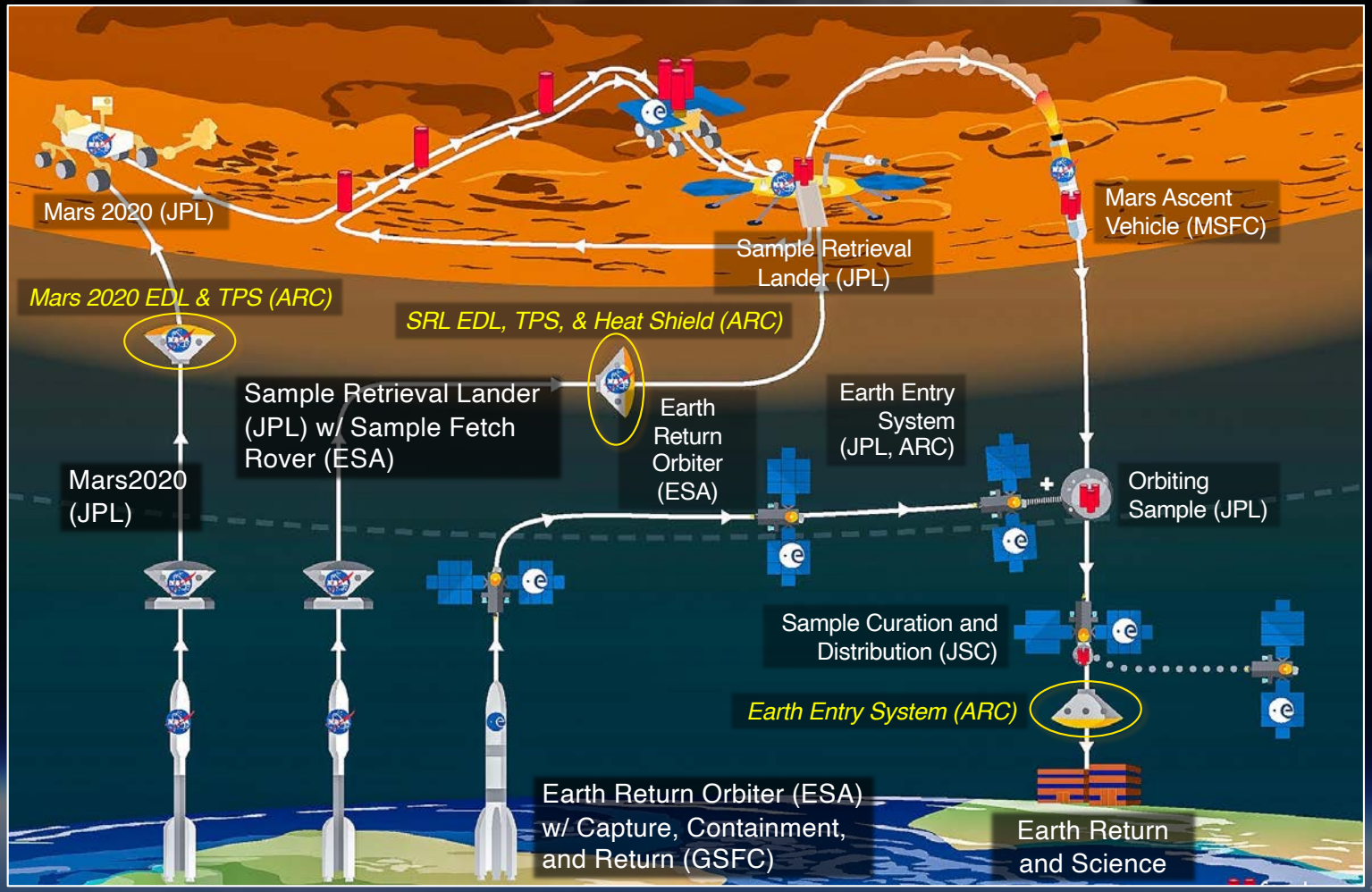

Ingenuity's Second Flight As Seen by Perseverance April 22, 2022


Helping the First Mars Helicopter Fly

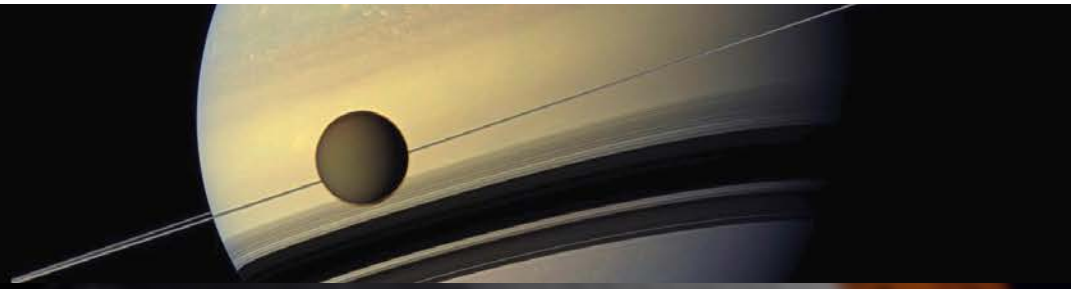

Perseverance Views Dust Devils Swirling Across Jezero Crater, June 01, 2022

# Mars Sample Return

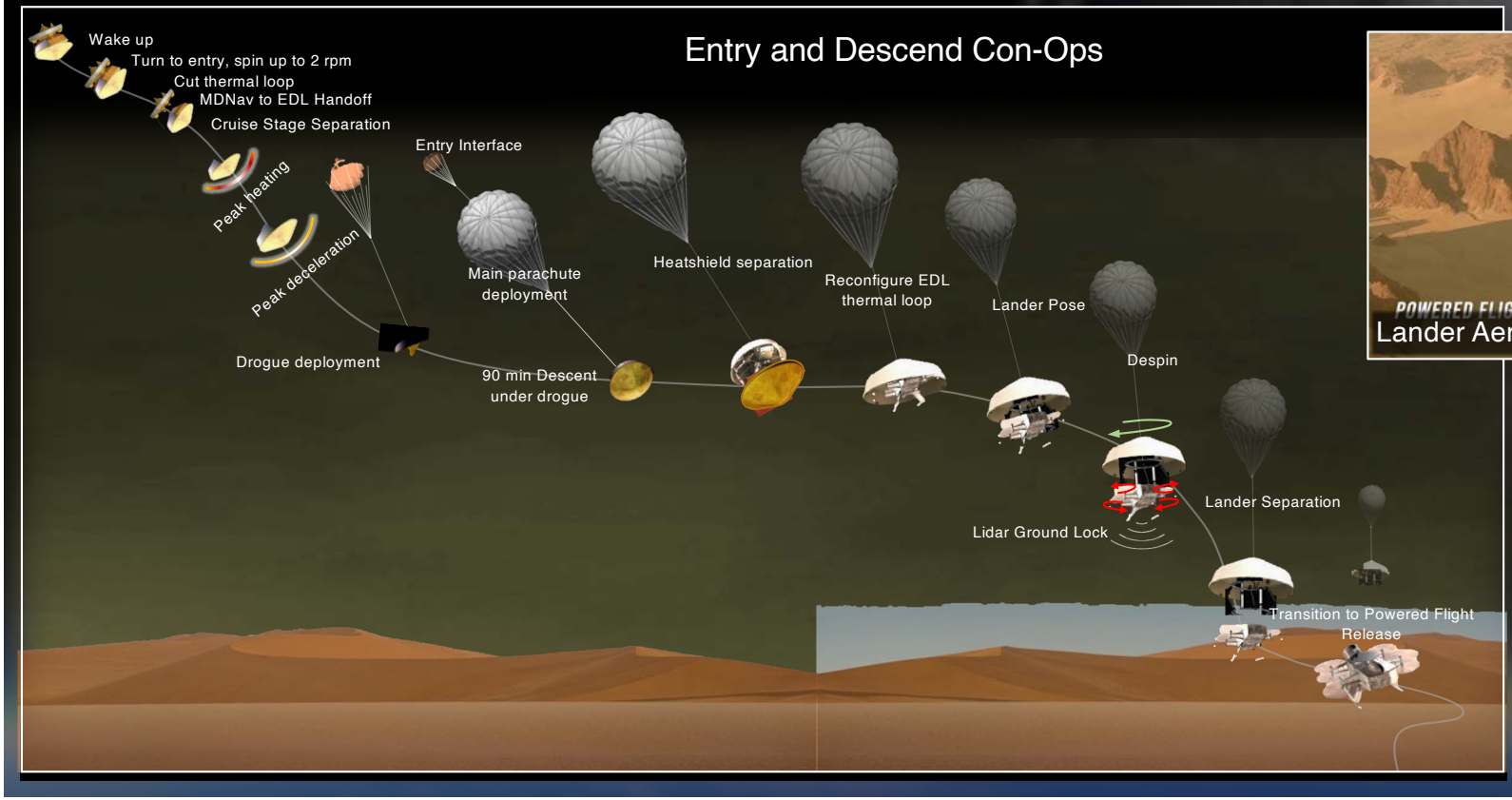


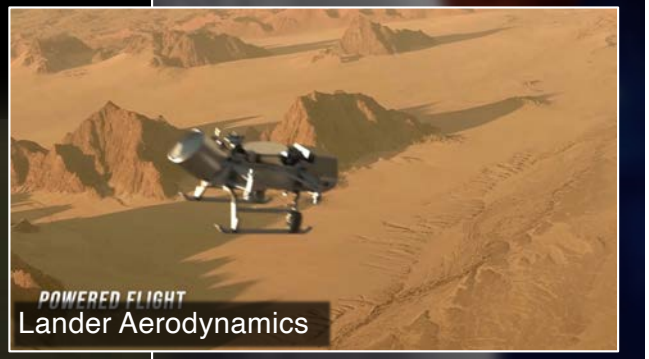



DRAGONFLY



## Entry and Descend Con-Ops

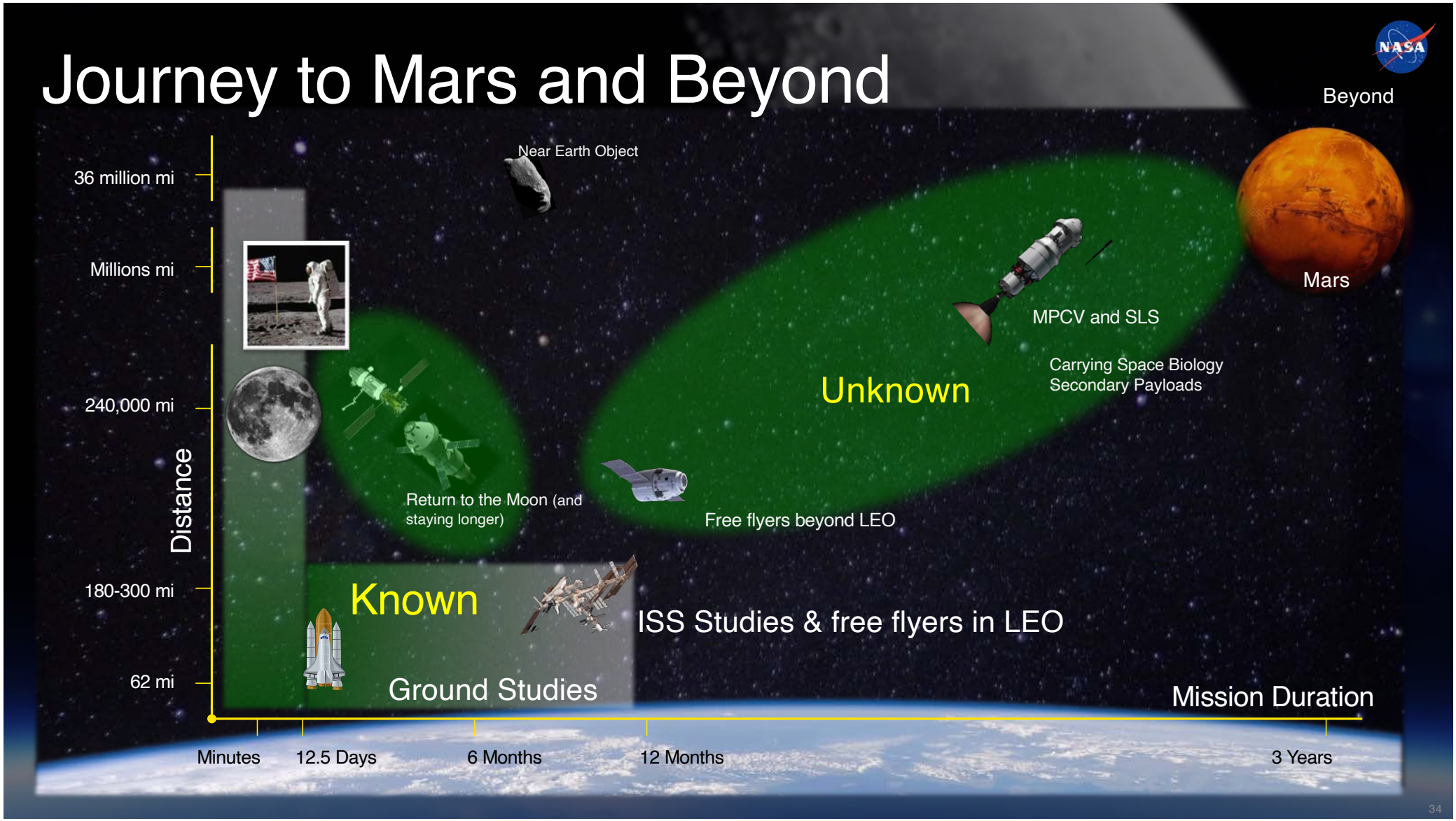



Lander Aerodynamics

Development, testing, and calibration of the H2 sensor

# Journey to Mars and Beyond



# Space Operations

*Launch and space operations, including the International Space Station, the commercialization of low-Earth orbit, and eventually, sustaining operations on and around the Moon*

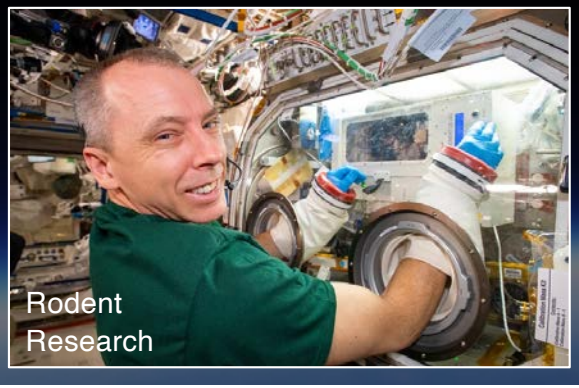
## International Space Station: Automation& Flight Projects


Astrobee + ISAAC

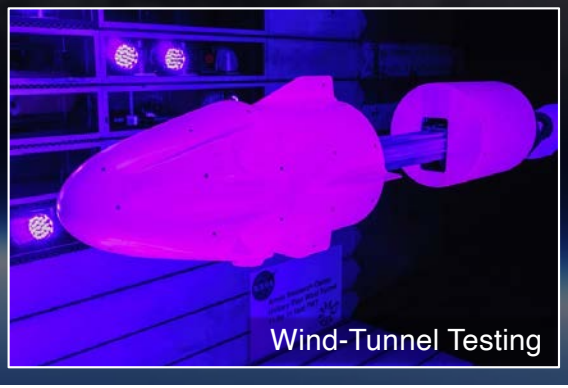

Playbook

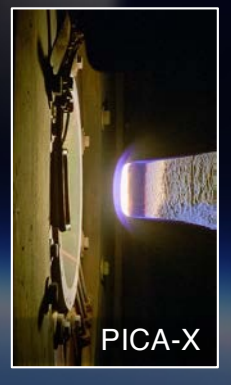
## Commercial Space

Pilot Training


Rodent Research


Cell Science / BioCulture System

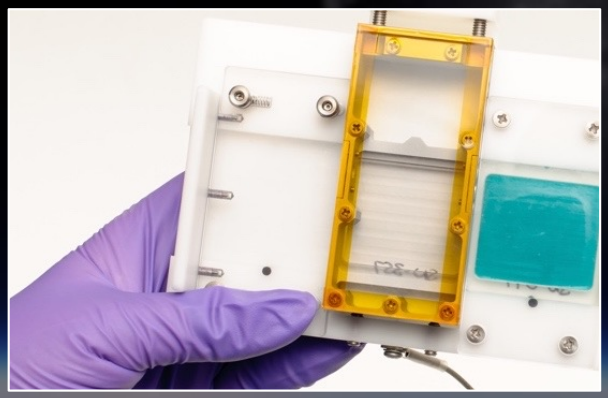

Wind-Tunnel Testing


PICA-X

# Space Biology

## Rodent Research

## Fruit Fly Labs



## Bioculture System Validation

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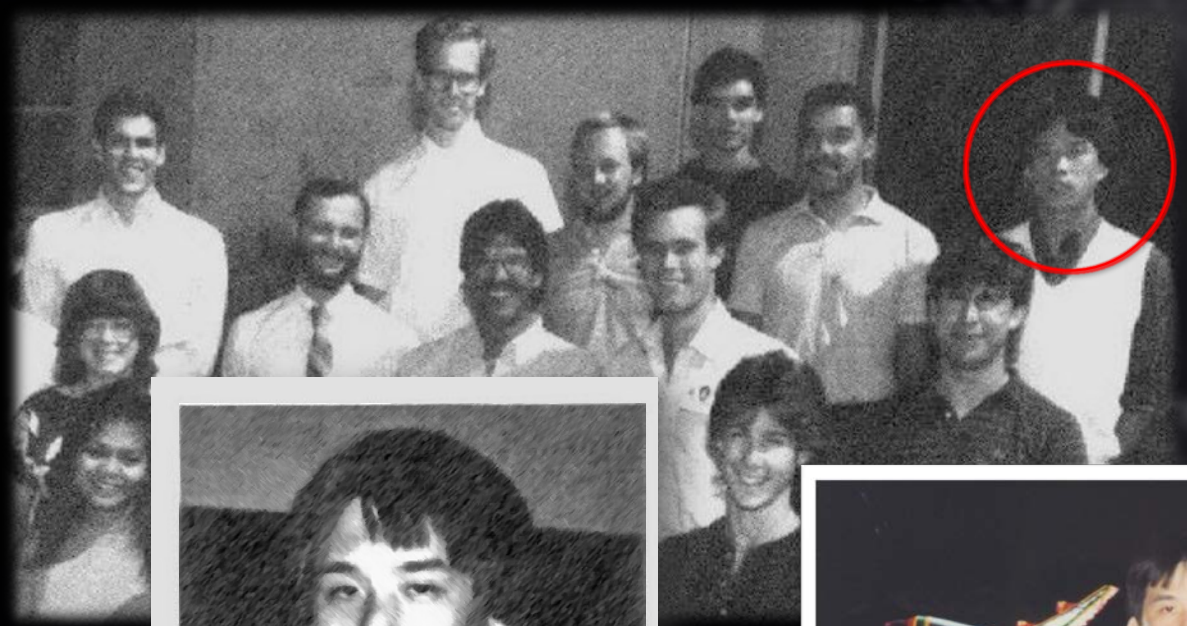
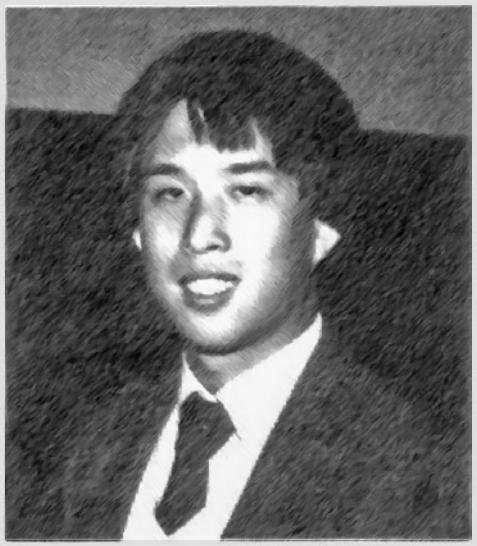


## CONTROL SURFACE SIMULATION

Guru P. Guruswamy
Sterling Federal Systems

Eugene L. Tu and Peter M. Goorjian
Applied Computational Fluids Branch
NASA Ames Research Center



Co-op Student —
Eugene L. Tu

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Information Technology
HPCC
NASA
CICT
NASA
Center for Robotic Exploration & Space Technologies
EARTH RIGHT NOW
MARS



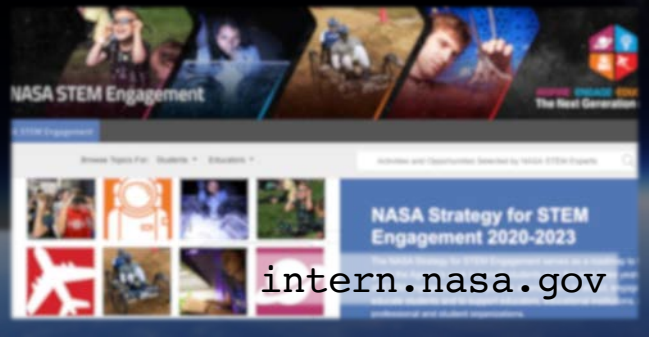
39


UNIVERSITY OF
CALIFORNIA BERKELEY.
Cal
STANFORD.
TO EUGENE —
BEST WISHES FROM BOTH SIDES
OF THE BAY!!! WE CAN CO-EXIST
PEACEFULLY IN SPACE —

# Opportunities at Ames

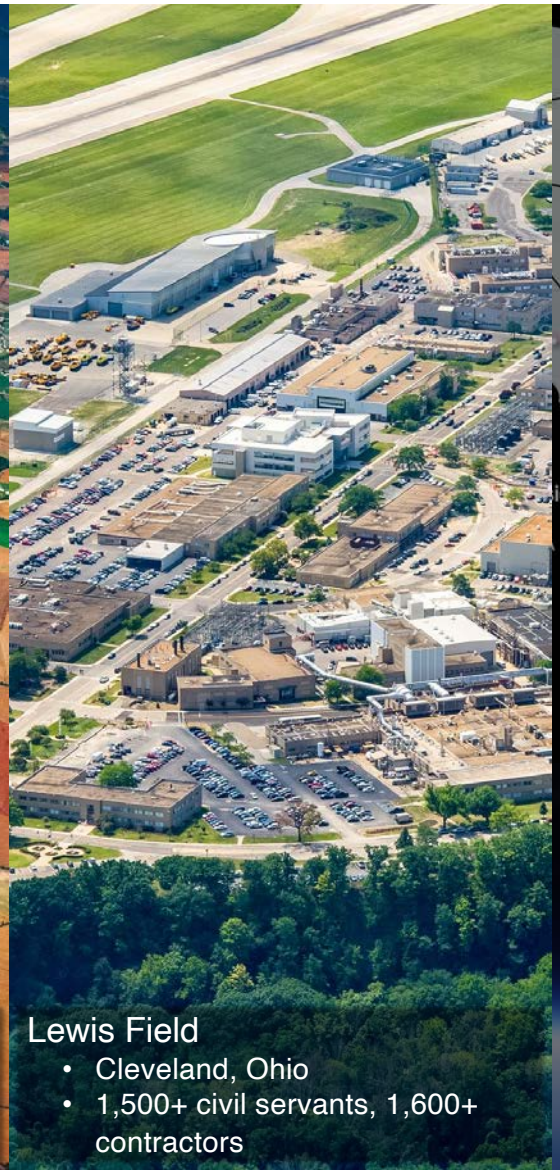
Upcoming openings:
- Computer Scientists
- Engineers: Aerospace, Software, Electrical, Materials, Systems
- Physical Scientists: Astrobiology, Biosciences, Space, and Earth Sciences
- Business Operations (HR, Public Affairs, Procurement, IT)


Pathways and Education Programs:
Internships, Fellowships, Intern Employment and Recent Graduate Program
- Engineering
- Physical Scientist
- Human Resources
- Finance
- Business Administration

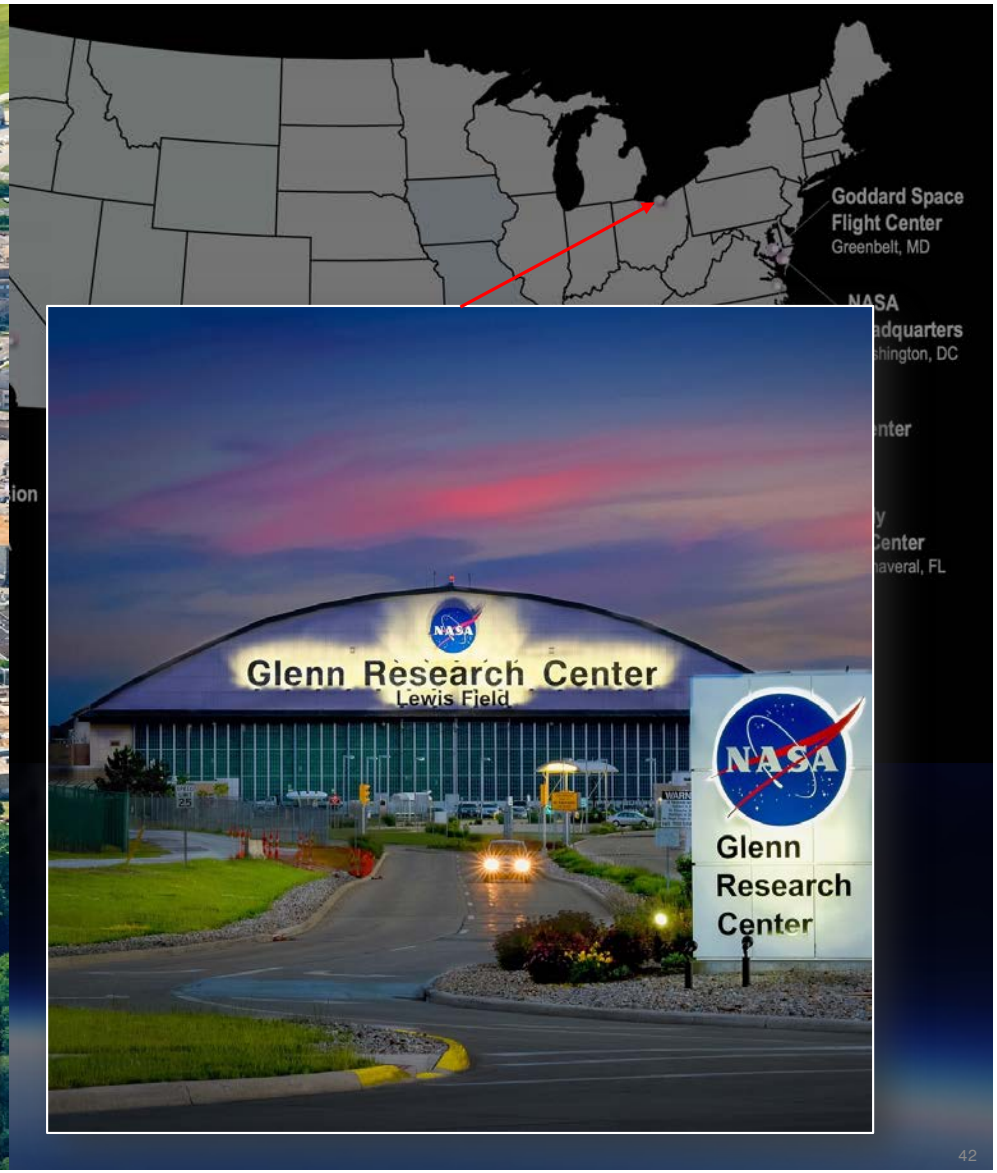




**Armstrong Test Facility**
- Sandusky, Ohio
- 20+ civil servants, 100+ contractors



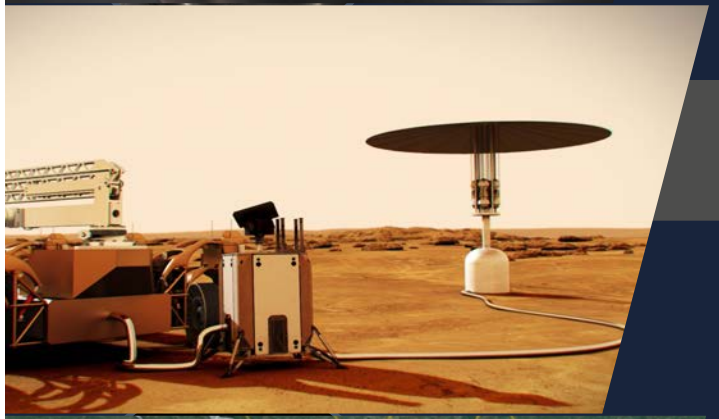
**Lewis Field**
- Cleveland, Ohio
- 1,500+ civil servants, 1,600+ contractors



# Glenn Core Competencies

Aircraft Propulsion

In-Space Propulsion & Cryogenics



Power, Energy Storage & Conversion

Materials & Structures for Extreme Environments

Communications Technology

Physical Sciences & Biomedical Tech


# Thank You!

Eugene.L.Tu@nasa.gov