Current and Future Prospects for International Cooperation in Planetary Sciences: A NASA Perspective

Steven Vance
Jet Propulsion Laboratory, California Institute of Technology
AOGS Planetary Science (PS) Section President
svance@jpl.caltech.edu

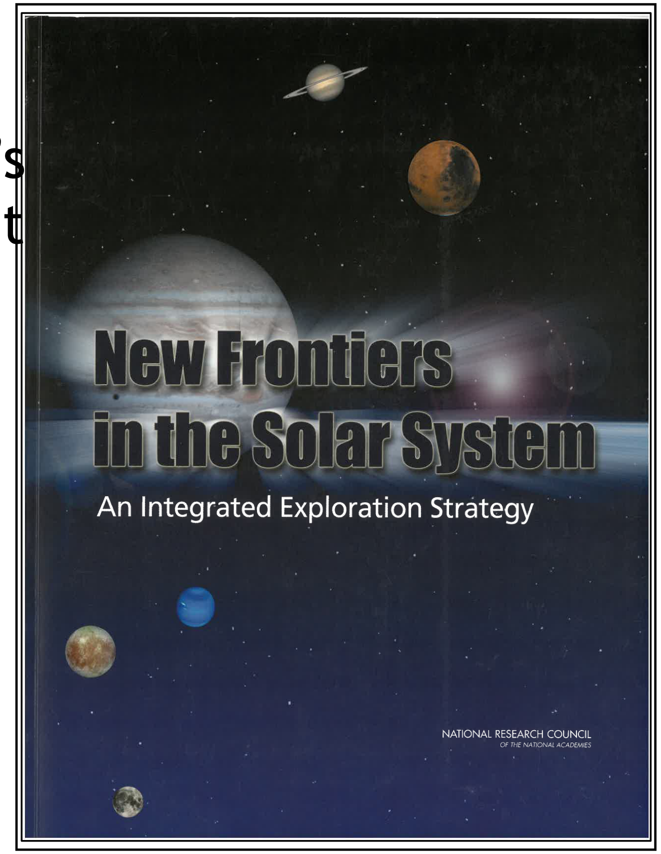
Jim Green
NASA Chief Scientist
January 2021

Planetary Science Decadal Reports

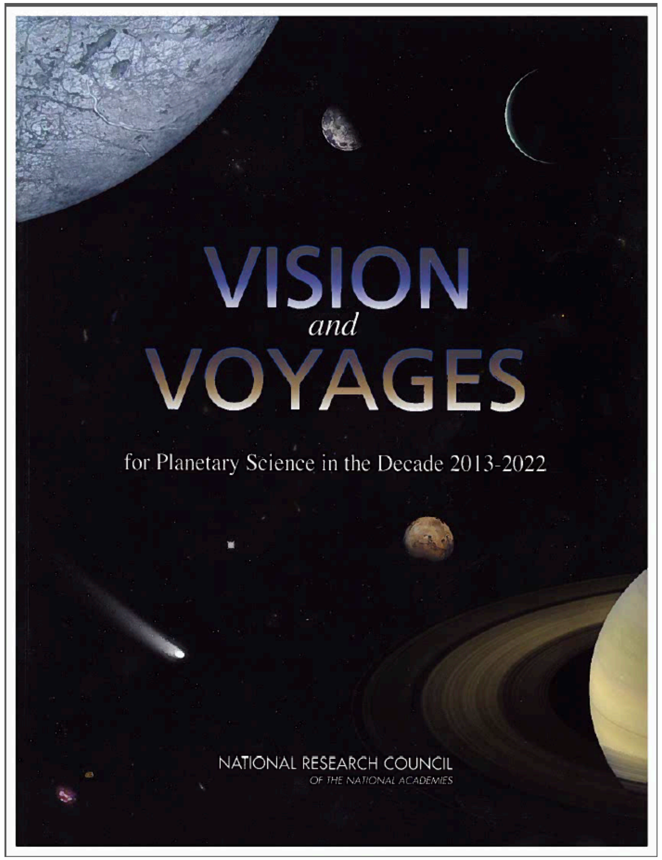
NASA'S Planetary Science Division's
Follows the broad strategy laid out
In the National Academy Decadal
Reports

3rd Planetary Decadal:
2023-2032
underway with report to
NASA
due 1st quarter 2022

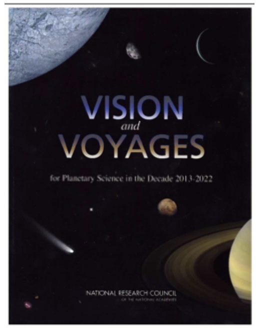
1st Planetary decadal: 2002-2012



2nd Planetary decadal: 2013-2022



Planetary Program Architecture
Recommended by the Planetary Decadal Survey



Mars 2020 Mission (Perseverance Rover) → 1)

Clipper Mission → 2)

Large Missions ("Flagship"-scale) - Strategic Missions

"Recommended Program"
(budget increase for JEO new start)

1) Mars Astrobiology Explorer-Cacher - descoped
2) Jupiter Europa Orbiter (JEO) - descoped
3) Uranus Orbiter & Probe (UOP)
4/5) Enceladus Orbiter & Venus Climate Mission

"Cost Constrained Program"
(based on FY11 Request)

1) Mars Astrobiology Explorer-Cacher - descoped
2) Uranus Orbiter & Probe (UOP)

"Less favorable" budget picture than assumed
(e.g., outyears in FY12 request)

Descope or delay Flagship mission

Discovery (PI Class)
$500M (FY15) cap per mission (exclusive of launch vehicle) and 24 month cadence for selection

New Frontiers (PI Class)
$1B (FY15) cap per mission (exclusive of launch vehicle) with two selections during 2013-22

Research & Analysis (5% above final FY11 amount then ~1.5%/yr)

Technology Development (6-8%)

Current Commitments (ie: Operating Missions)

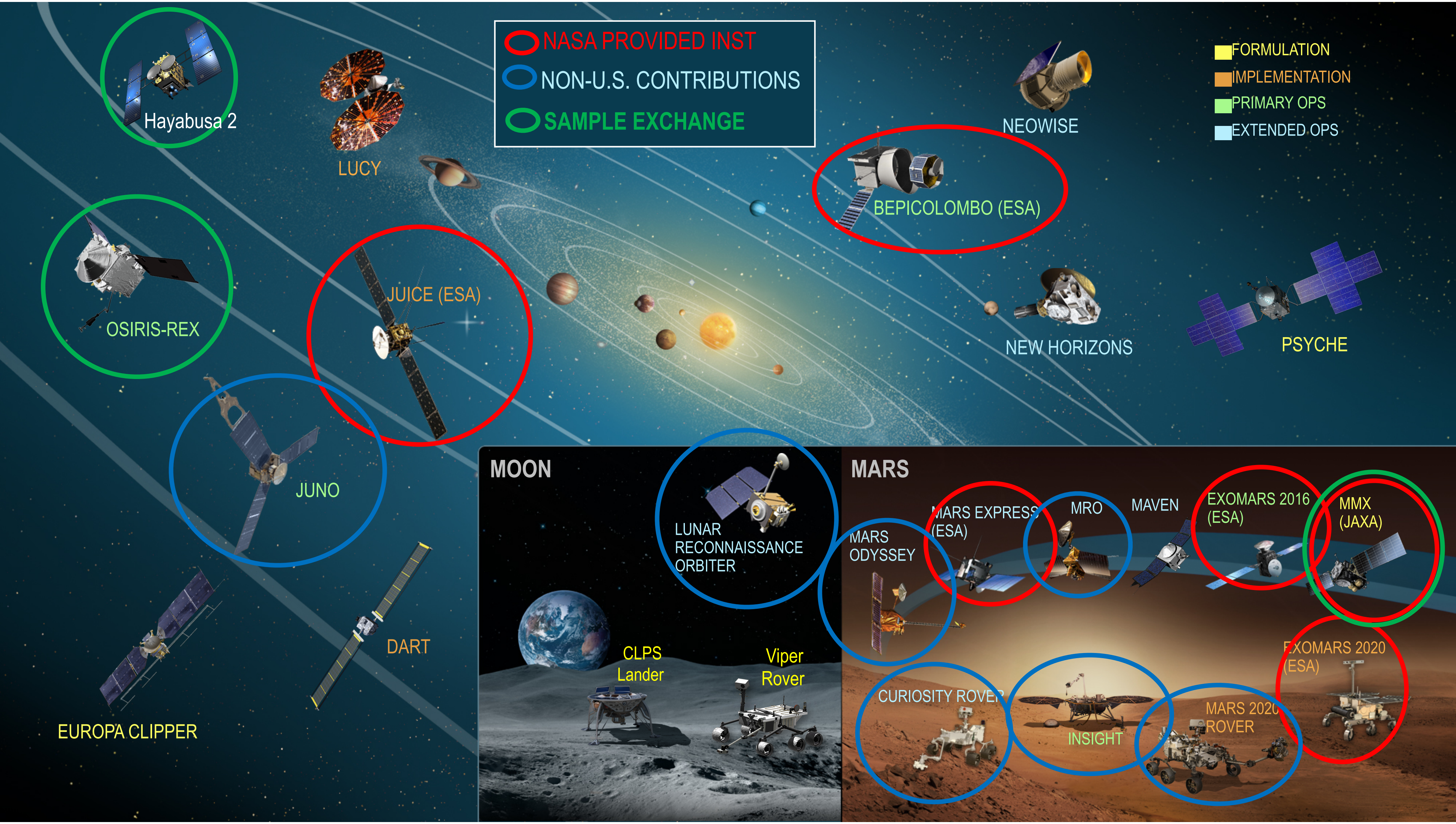
The cost information contained in this presentation is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

How does NASA Cooperate Internationally?

- Foreign policy objectives, public diplomacy and international cooperation have been part of NASA since its inception
  - Directed by the 1958 National Aeronautics and Space Act:
    - NASA will cooperate with other nations
    - Disseminate information as broadly as practicable
  - Goal of the 2010 National Space Policy: *Expand international cooperation on mutually beneficial space activities to: broaden and extend the benefits of space; further the peaceful use of space; and enhance collection and partnership in sharing of space-derived information*
- Current NASA international cooperation:
  - Over 700 active international agreements
  - 8 partners account for 50% of the agreements:
    - France, Germany, ESA, Japan, UK, Italy, Canada, Russia
  - By mission area: 2/3 are in science missions
  - By region: 1/2 are with partners in Europe

Guidelines for International Cooperation

- Consistent with U.S. law and foreign policy objectives
- International partners are *generally* government agencies
- Projects/Partnerships:
  - Must have scientific and technical merit
  - Must benefit NASA
  - No exchange of funds
  - Have clear managerial and technical interfaces
    - "Meet at the interface" (i.e.- no joint development, limit tech transfer)
  - Documented in written, binding agreements, closely coordinated with the U.S. Department of State and other U.S. Government agencies
- Decision meetings can be Bilaterals or Multilateral
- Types of collaborations:
  - ○ NASA accepts foreign instruments on NASA missions
  - ○ NASA provides instruments to foreign missions
  - ○ Exchange of extra-terrestrial samples


NASA PROVIDED INST
NON-U.S. CONTRIBUTIONS
SAMPLE EXCHANGE
FORMULATION
IMPLEMENTATION
PRIMARY OPS
EXTENDED OPS
Hayabusa 2
LUCY
NEOWISE
BEPICOLOMBO (ESA)
OSIRIS-REX
JUICE (ESA)
NEW HORIZONS
PSYCHE
JUNO
EUROPA CLIPPER
DART
MOON
LUNAR RECONNAISSANCE ORBITER
CLPS Lander
Viper Rover
MARS
MARS ODYSSEY
MARS EXPRESS (ESA)
MRO
MAVEN
EXOMARS 2016 (ESA)
MMX (JAXA)
EXOMARS 2020 (ESA)
CURIOSITY ROVER
INSIGHT
MARS 2020 ROVER

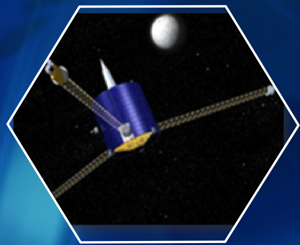
Non-U.S. instruments on NASA missions (Examples)

Discovery Program: PI Competitive

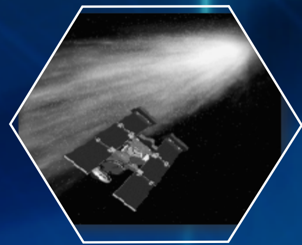
NEO characteristics
NEAR
(1996-1999)

Mars evolution
Mars Pathfinder
(1996-1997)

Lunar formation
Lunar Prospector
(1998-1999)



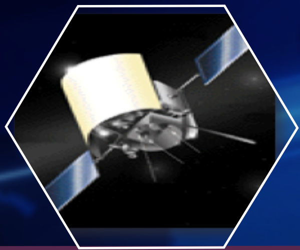
Nature of dust/coma
Stardust
(1999-2011)



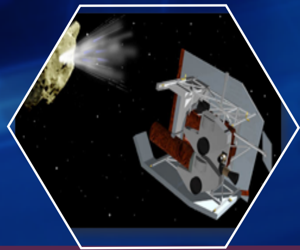
Solar wind sampling
Genesis
(2001-2004)

Comet Diversity
CONTOUR
(2002)

Mercury Environment
MESSENGER
(2004-2015)

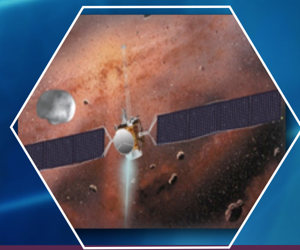


Comet Internal Structure
Deep Impact
(2005-2012)



Lunar Internal Structure
GRAIL
(2011-2012)

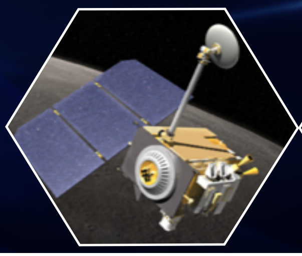
Main-belt Asteroids
Dawn
(2007-2019)



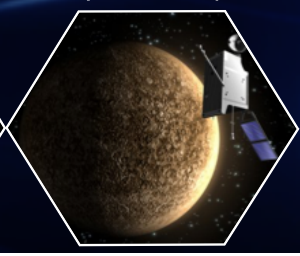
Exoplanets
Kepler
(2009-TBD)

Currently Operating

Lunar Surface
LRO
(2009-TBD)



ESA/Mercury Surface
Strofio
(2017-TBD)



Mars Interior
InSight
(2018)

Trojan Asteroids
Lucy
(2021)

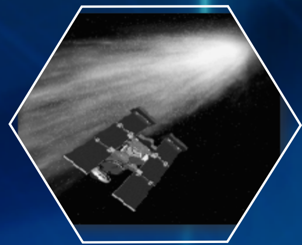
Metal Asteroid
Psyche
(2022)

Martian Moons
MMX/MEGANE
(2024)

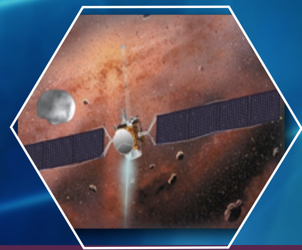
Discovery Program: International Participation

Mars evolution
Mars Pathfinder
(1996-1997)

Nature of dust/coma
Stardust
(1999-2011)

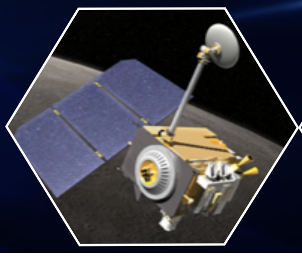


Main-belt Asteroids
Dawn
(2007-2019)

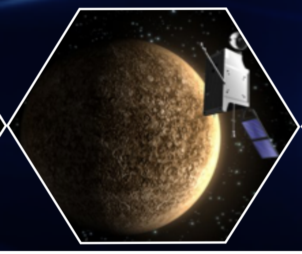


Currently Operating

Lunar Surface
LRO
(2009-TBD)



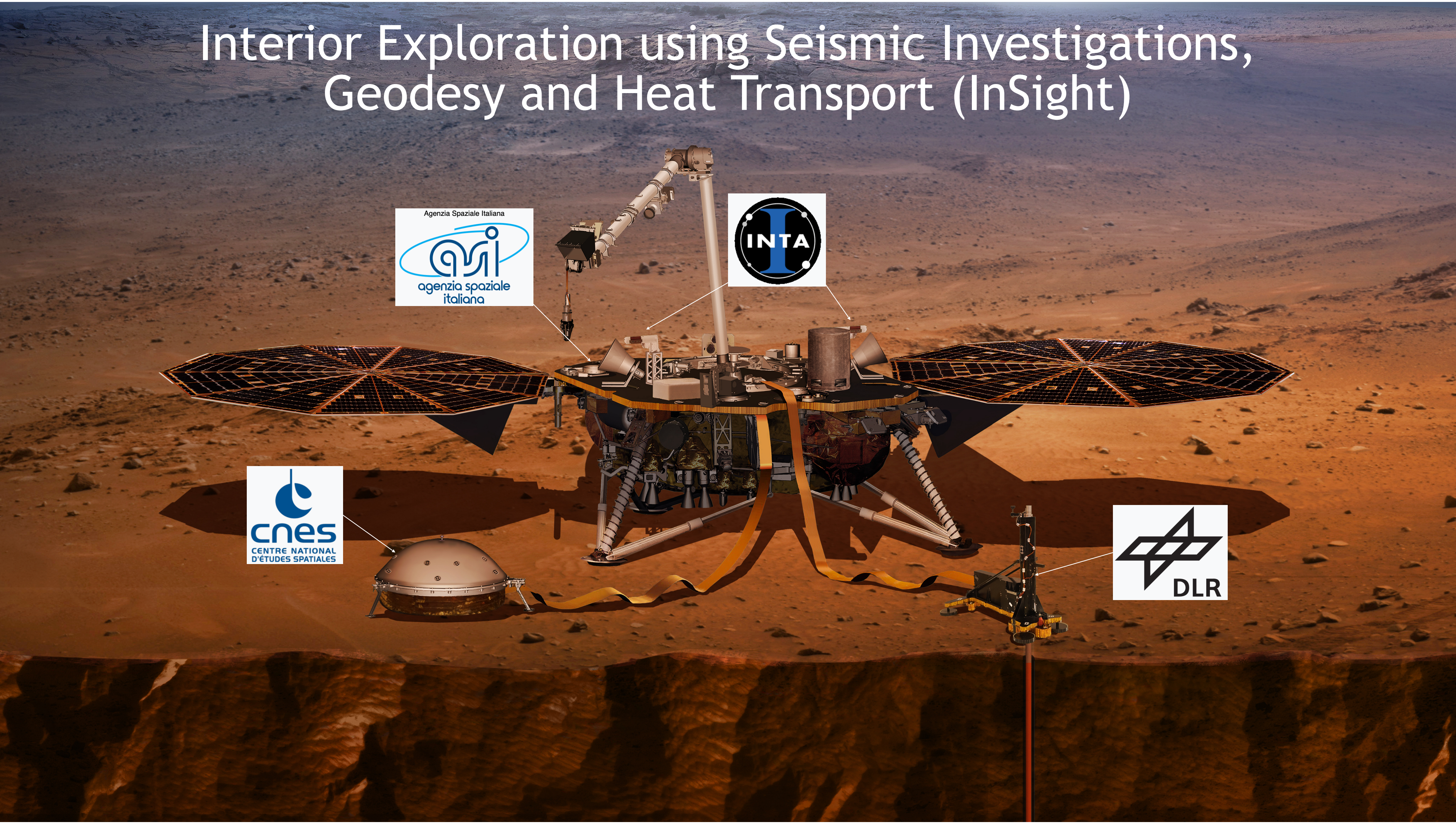
ESA/Mercury Surface
Strofio
(2017-TBD)

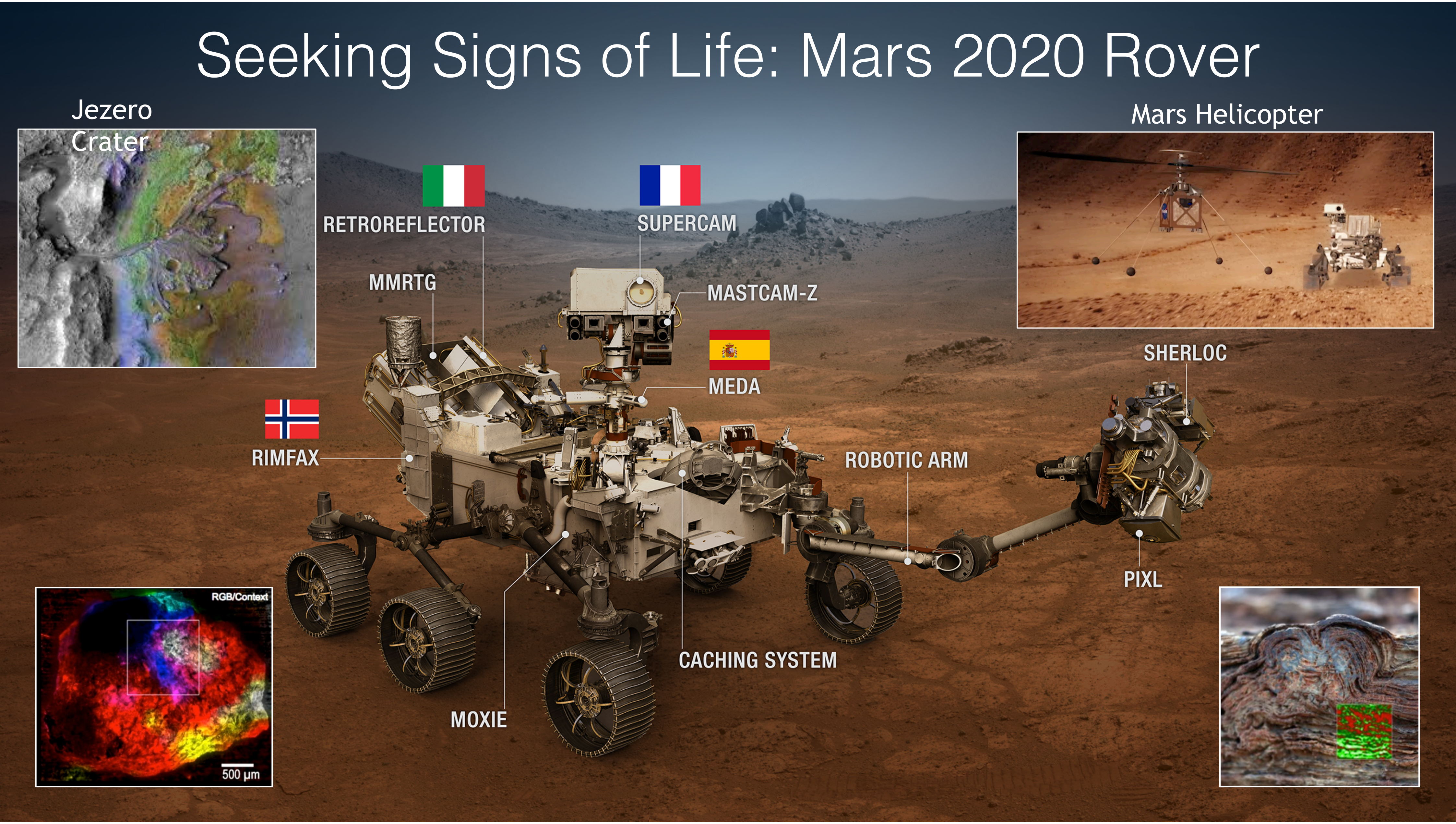


Mars Interior
InSight
(2018)

Martian Moons
MMX/MEGANE
(2024)

Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)

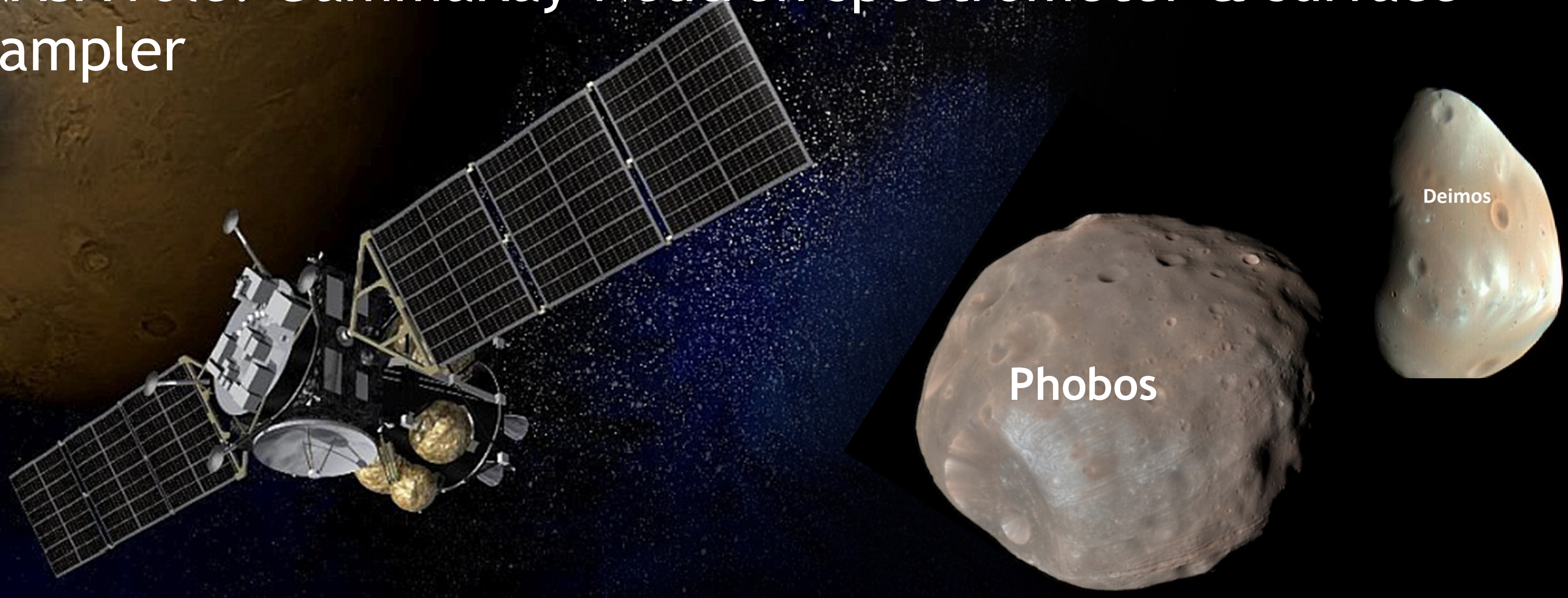


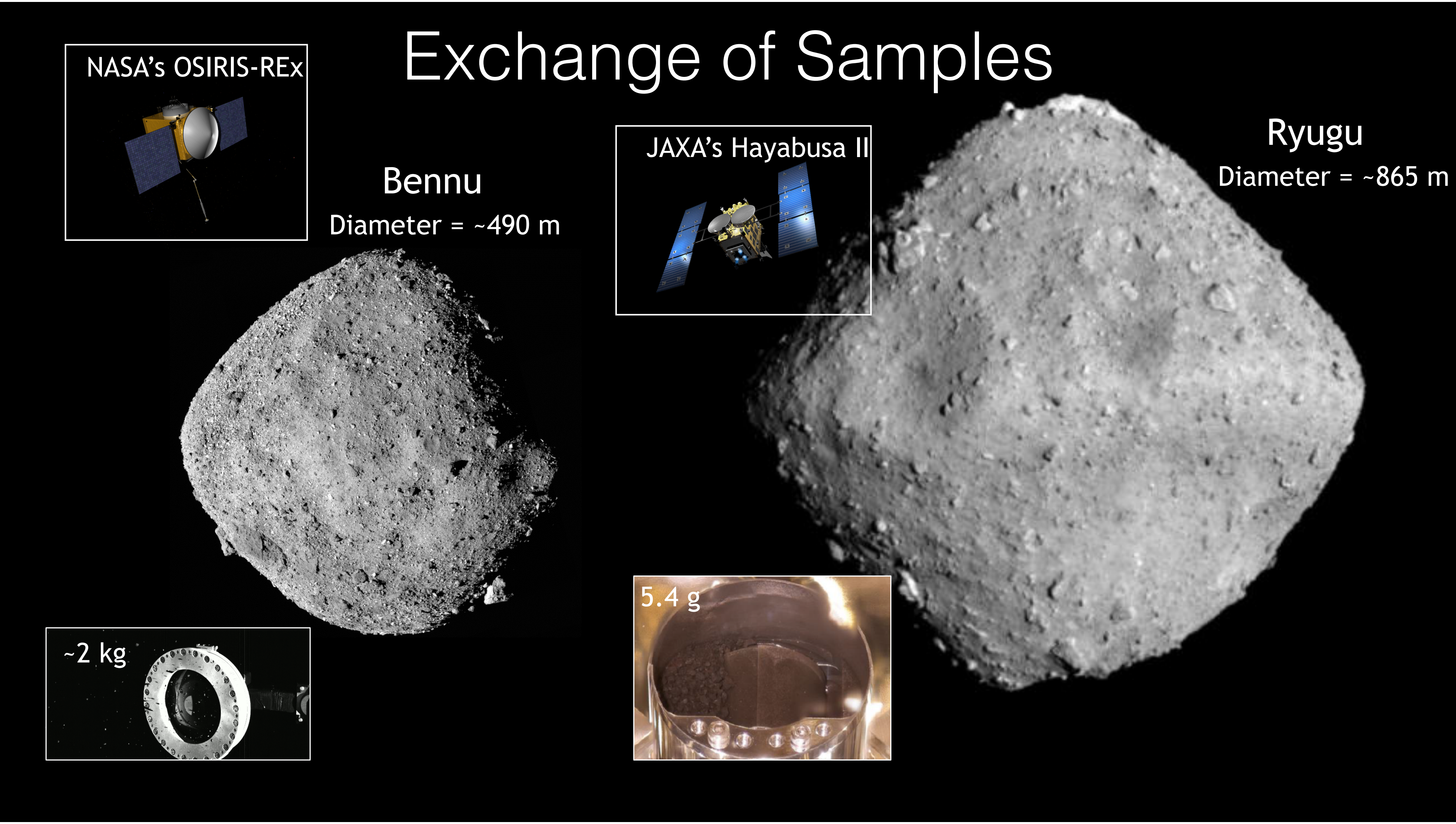

Seeking Signs of Life: Mars 2020 Rover
Jezero Crater
Mars Helicopter
RETROREFLECTOR
SUPERCAM
MMRTG
MASTCAM-Z
MEDA
RIMFAX
SHERLOC
ROBOTIC ARM
PIXL
CACHING SYSTEM
MOXIE
RGB/Context
500 μm

NASA provided instruments to non-U.S. missions (Examples)

JAXA: Martian Moons eXploration (MMX) Mission

- Sample Return mission to Phobos or Demos
- COSPAR Decision: Category V-**Unrestricted Earth return**
- NASA role: GammaRay-Neutron spectrometer & surface sampler

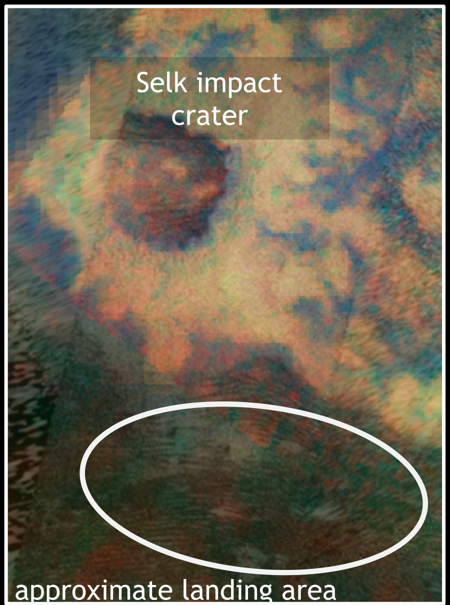


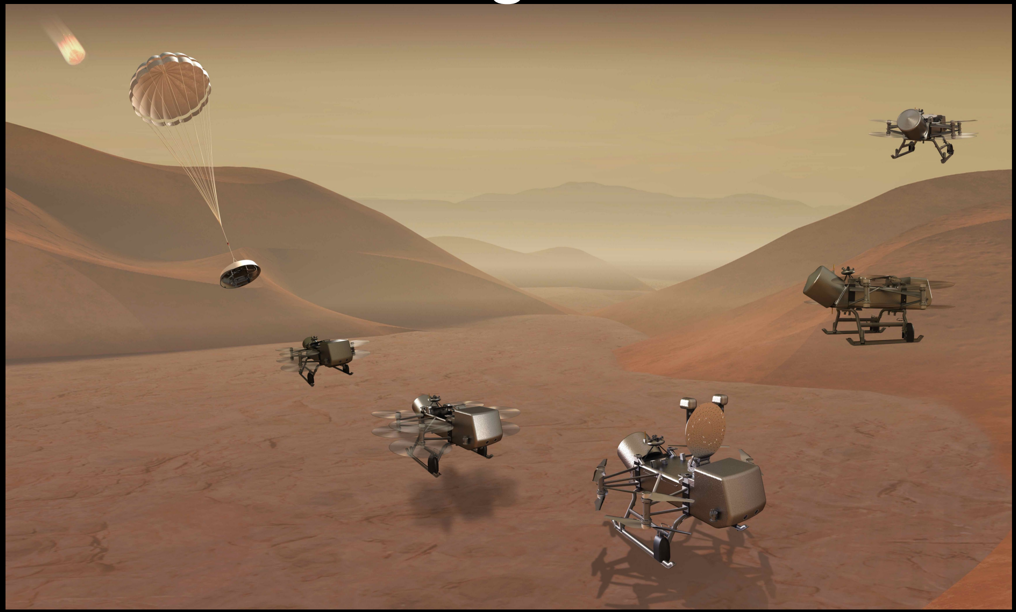

Exchange of Samples
NASA's OSIRIS-REx
Bennu
Diameter = ~490 m
JAXA's Hayabusa II
Ryugu
Diameter = ~865 m
~2 kg
5.4 g

Future Collaborative Missions

In Situ Exploration of Saturn's Moon Titan, an Organic-Rich Ocean World

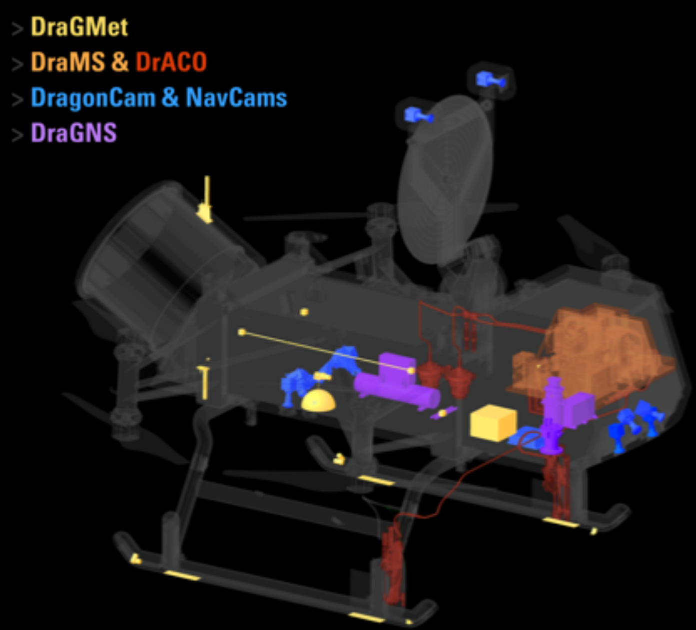
DRAGONFLY



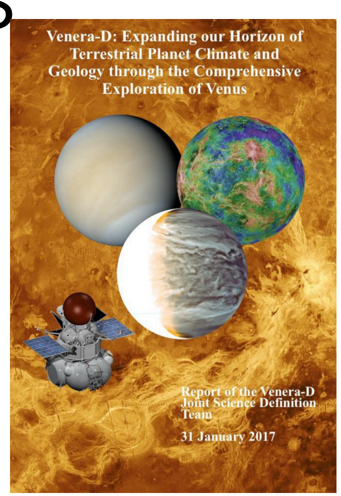


https://dragonfly.jhuapl.edu

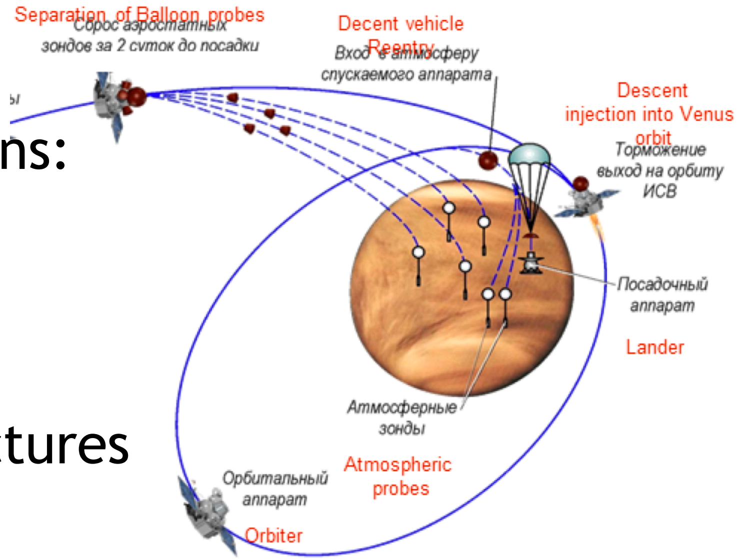
- **Science and Engineering Instruments**
  - DraMS: Mass Spectrometer (GSFC, CNES)
  - DrACO: Drill for Acquisition of Complex Organics (Honeybee Robotics)
  - DraGMet: Geophysics & Meteorology Package (APL, JAXA Lunar-A seismometer)
  - DragonCam: Camera Suite (MSSS)
  - DraGNS: Gamma-ray Neutron Spectrometer (APL, LLNL, GSFC, Schlumberger)
  - DrEAM: Atmospheric entry measurements (ARC, DLR)



Venus Missions On-going Studies

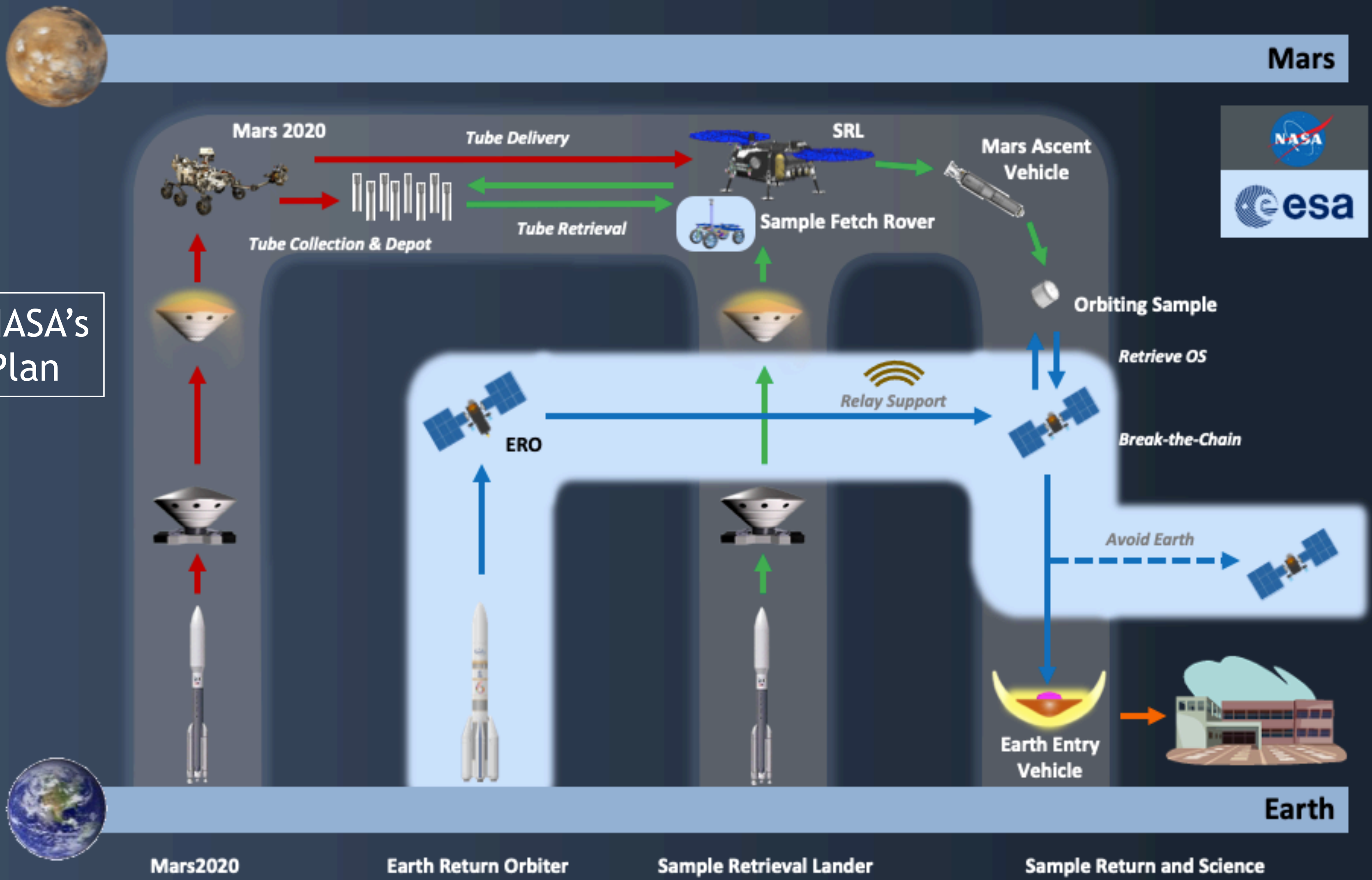


- NASA/RSA created a Venera-D Joint Science Definition Team
  - Completed an initial study report Jan 31, 2017
  - Defines all the top decadal science that can be accomplished versus a series of notional platforms
- Baseline missions:
  - Orbiter: Polar 24-hour orbit with a lifetime greater than 3 years- Can trade orbiter period for communication with other elements of mission for more than 24h
  - Lander: (updated VEGA) 2+ hours on the surface
- Other components discussed as potential augmentations:
  - Free flying aerial platform and balloons
  - Sub-satellite
  - Small long-lived stations
- Next steps:
  - Focus shifts to realistic mission designs & architectures



MSR Architecture Overview

Status of NASA's Current Plan



All contents represent notional planning and are for discussion purposes only

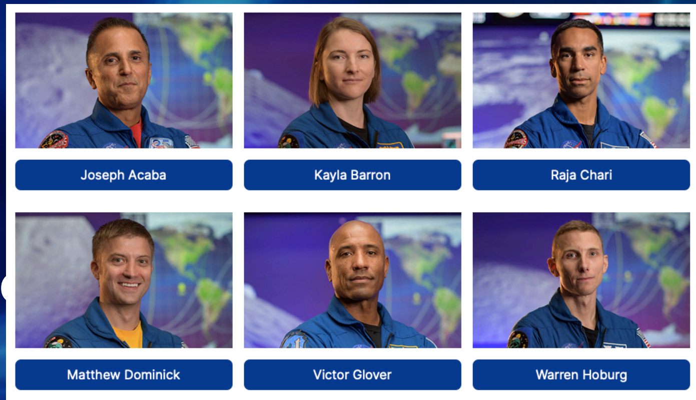
Partnerships under Discussion
Lunar Science & Exploration Missions

Artemis Accords: International Guidelines

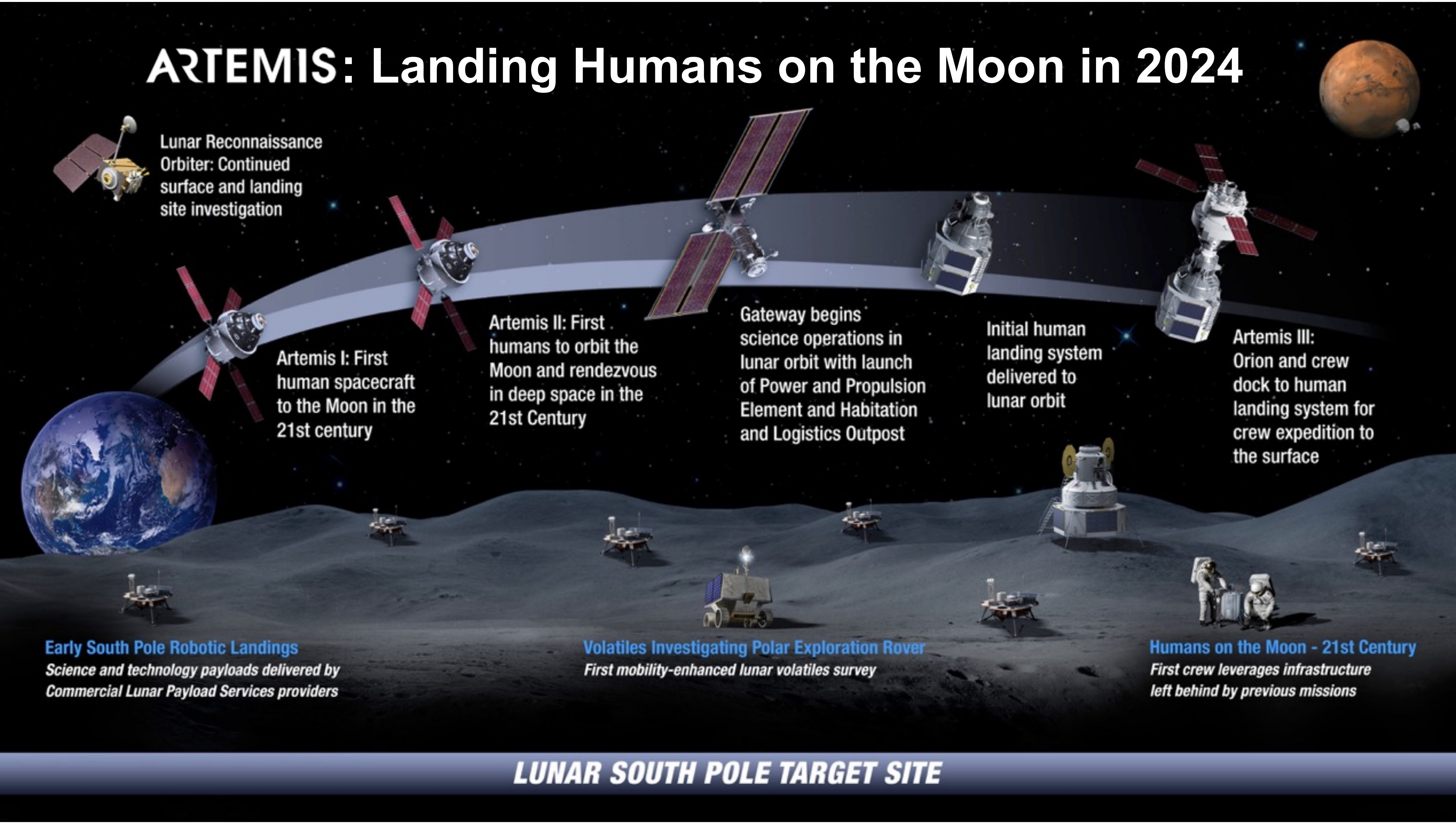
Signers: US, Australia, Canada, Japan, Luxembourg, Italy, UK, UAE, Ukraine

- Peaceful Purposes
- Transparency
- Interoperability
- Emergency Assistance
- Registration of Space Obje
- Release of Scientific Data
- Protecting Heritage
- Space Resources
- Deconfliction of Activities
- Orbital Debris and Spacecraft Disposal

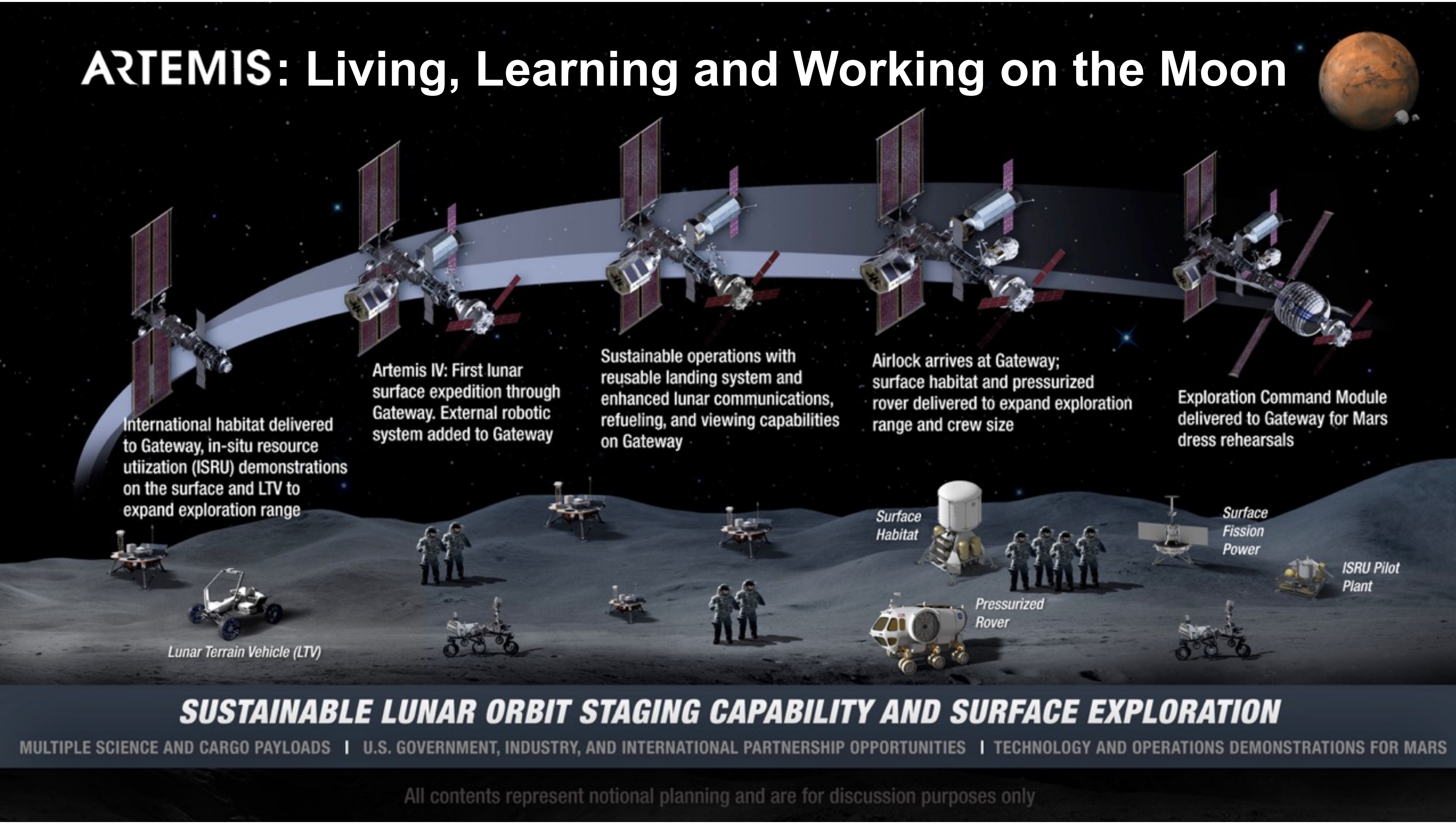
Artemis Astronauts



ASTROBOTIC
Tyvak
A Terran Orbital Corporation
BLUE ORIGIN
SPACEX
ceres robotics
Commercial Lunar Payload Services (CLPS)
SNC SIERRA NEVADA CORPORATION
DEEP SPACE SYSTEMS
ORBITBeyond
Delivering to the Moon
Working with industry to deliver science and technology payloads to the lunar surface
DRAPER
FIREFLY AEROSPACE
MOON EXPRESS
Masten
ROCKET TECHNOLOGY INNOVATORS
LOCKHEED MARTIN
INTUITIVE MACHINES



ARTEMIS: Landing Humans on the Moon in 2024
Lunar Reconnaissance Orbiter: Continued surface and landing site investigation
Artemis I: First human spacecraft to the Moon in the 21st century
Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st Century
Gateway begins science operations in lunar orbit with launch of Power and Propulsion Element and Habitation and Logistics Outpost
Initial human landing system delivered to lunar orbit
Artemis III: Orion and crew dock to human landing system for crew expedition to the surface
Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers
Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey
Humans on the Moon - 21st Century
First crew leverages infrastructure left behind by previous missions
LUNAR SOUTH POLE TARGET SITE


ARTEMIS: Living, Learning and Working on the Moon
International habitat delivered to Gateway, in-situ resource utiization (ISRU) demonstrations on the surface and LTV to expand exploration range
Artemis IV: First lunar surface expedition through Gateway. External robotic system added to Gateway
Sustainable operations with reusable landing system and enhanced lunar communications, refueling, and viewing capabilities on Gateway
Airlock arrives at Gateway; surface habitat and pressurized rover delivered to expand exploration range and crew size
Exploration Command Module delivered to Gateway for Mars dress rehearsals
Lunar Terrain Vehicle (LTV)
Surface Habitat
Pressurized Rover
Surface Fission Power
ISRU Pilot Plant
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
All contents represent notional planning and are for discussion purposes only

Questions?

DRAGONFLY

In Situ Exploration of Saturn's Moon Titan, an Organic-Rich Ocean World

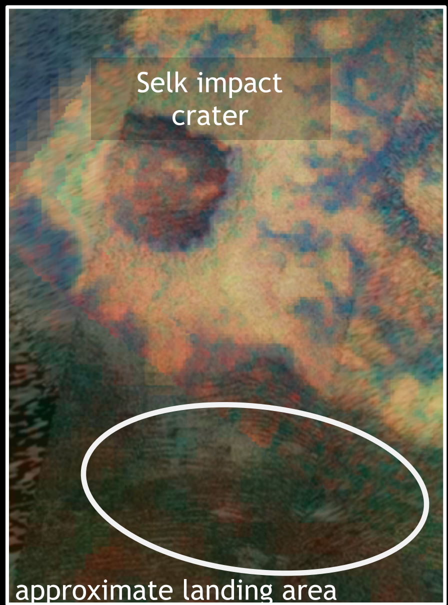
Science Objectives

- Analyze chemical components and processes that produce biologically relevant compounds
- Measure atmospheric and surface conditions
- Constrain processes that mix organics with water
- Search for chemical evidence of biological processes

Titan's dense atmosphere and low gravity make it easier to fly there than on Earth. By flying, Dragonfly can explore and sample materials in different areas, including organic sand dunes and impact crater deposits where organics may have mixed with water.

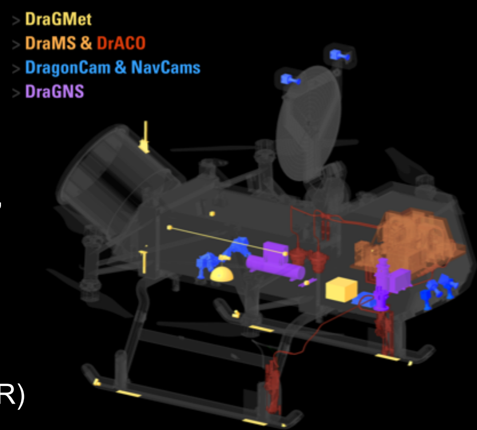
Mission Plan

- Launch in 2027; Titan arrival mid-2030s
- ~3.3 years of exploration, traversing over 100 miles to more than 24 unique landing sites
- Current activities: Preliminary design and hardware testing in the Titan environment



Science and Engineering Instruments

- DraMS: Mass Spectrometer (GSFC, CNES)
- DrACO: Drill for Acquisition of Complex Organics (Honeybee Robotics)
- DraGMet: Geophysics & Meteorology Package (APL, JAXA Lunar-A seismometer)
- DragonCam: Camera Suite (MSSS)
- DraGNS: Gamma-ray Neutron Spectrometer (APL, LLNL, GSFC, Schlumberger)
- DrEAM: Atmospheric entry measurements (ARC, DLR)



Title: Current and Future Prospects for International Cooperation in Planetary Sciences: A NASA Perspective

Authors: Steven D. Vance, James Green

Abstract:

Planetary exploration investigates objects and physical processes throughout the solar system, and beyond. The scope of possible scientific investigations can easily outpace available resources. International partnerships can lead to new innovations. NASA has engaged in many such partnerships. We will describe some examples of such international partnerships, and successes and lessons learned. We will also describe mechanisms for international contributions to NASA missions and science. Over 500 white papers have been received by the National Academy of Sciences as input to the Planetary Science Decadal Survey that will serve as its guide for prioritizing missions in the 2023-2033 timeframe, many will require international participation.