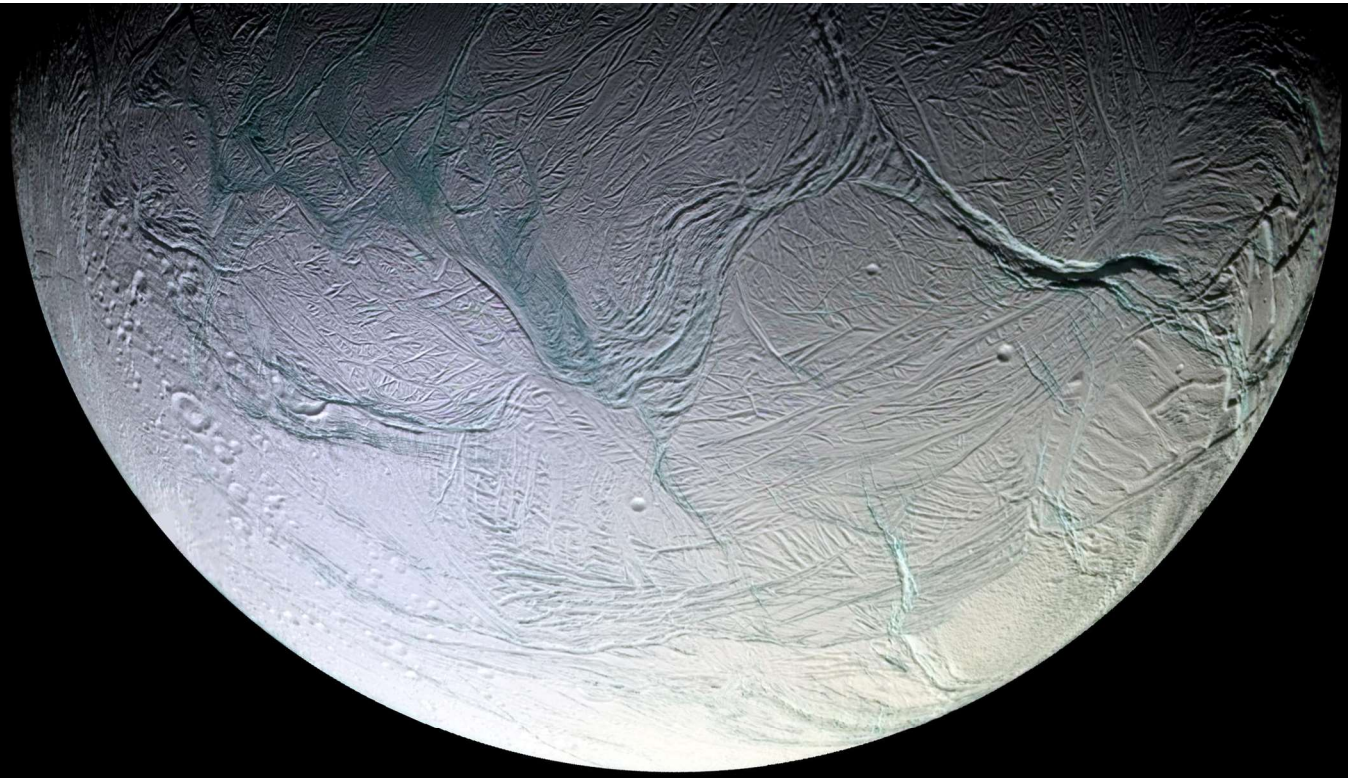

Contamination Control Engineering at JPL

NASA Johnson Space Center - ES4 Materials Branch Tech Talk
November 14, 2016

Carlos Soares
Technical Group Supervisor – Contamination Control Engineering [353D]
Propulsion, Thermal and Materials Engineering Section [3530]

Jet Propulsion Laboratory
California Institute of Technology

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Agenda

- Introduction to the Propulsion, Thermal and Materials Engineering Section at JPL
- Contamination Control Engineering [353D]
- JPL Missions - Contamination Control activities and Challenges
  - Mars Missions
    - InSight: SEIS Instrument
    - Mars 2020: Timeline, Flight System, Instruments/Science
    - Proposed Mars Helicopter
    - Potential Mars Sample Return
  - Icy Moons
    - Europa Mission / Potential Europa Lander
    - Enceladus
  - Asteroids
    - Asteroid Robotic Redirect Mission (ARRM)
    - Psyche
  - Earth Science Missions and Instruments
    - ECOSTRESS
    - Orbital Carbon Observatory OCO-3
    - NISAR
  - Other missions
  - JPL Materials & Processes
  - Typical Workflow
  - Environmental Testing
  - Missions Integration & Testing
- Concluding Remarks

PROPULSION, THERMAL, AND MATERIALS ENGINEERING SECTION 3530

Virgil Mireles, Section Manager
Gani B. Ganapathi, Deputy Section Manager

TECHNICAL STAFF:
J. Bellan **J. Brophy**
D. Goebel **J. Lyra**

Section 353 Employees

JPL Standard – 137
Student/Suppl.– 5
Total = 142

3513 – SECT 353 BUSINESS ADMIN
Sonia Mejia, Manager

Carolyn Murray, Admin Liaison
Elly Ponce, Business Admin
Jan Dumlao, Business Admin

Staff Assistants
Kris Katagiri – S Monica Marquez-King
Hope Norton

353A
PROPULSION, THERMAL, & MATERIALS SYSTEMS
Lee K. Johnson

P. Bhandari
G. Birur (IEP)
S. D'Agostino
C. Guernsey
D. Klein
J. Polk
E. Sunada

353B
ELECTRIC PROPULSION
Ira Katz

T. Albertson (PDE)
V. Chaplin (ECH)
R. Conversano (ECH)
R. Hofer (GL)
B. Jorns
S. Leifer
R. Lobbia
A. Lopez Ortega
C. Marrese-Reading
Y. Mikellides
N. Niblett
S. Snyder
R. Swindlehurst

353C
MATERIALS ENG., TEST & EVALUATION
Bryan W. McEnerney

D. Aldi
K. Beckwith (ECH)
E. Bradford (ECH)
S. Chan
Na. Chen (ECH)
J. Denman (PT)
G. Forsberg
M. Gallegos (LW)
L. Grimes-Ledesma
M. Hetzel (GL)
M. Knopp
D. Lewis (GL)
N. Low
J. Mejia-Ariza
M. Petkov
M. Smithfield
W. Sokolowski
C. Zhou

353D
CONTAMINATION CONTROL ENGINEERING
Carlos E. Soares

J. Anderson
B. Blakkolb (GL)
P. Boeder
N. Chen (ECH)
S. Chung
N. Ferraro
P. Hansen
S. Liao
M. Sylvia

353E
ANALYTICAL CHEMISTRY & MATERIALS DEVELOPMENT
Mark S. Anderson

A. Azad
S. Carnes
M. Duran
Y. Goreva
N. Heinz (ECH)
S. Jones
S. Kim
J. Mennella
D. Soules
G. Voecks (IEP)
W. Warner

353F
INSTRUMENT AND PAYLOAD THERMAL ENGINEERING
Jose G. Rivera

A. Aboobaker
E. Farias (ECH)
B. Hernandez (PT)
J. Hua
F. Kelly
Ja. Kempenaar
E. Kwack
H. Ochoa
H. Pham
N. Pootrakul
M. Redmond
B. Shreckengost (GL)
C. Smith (ECH)
R. Somawardhana
H. Tseng

353G
SPECIAL PROGRAMS THERMAL ENGINEERING
Charles J. Phillips

B. Briggs
D. Bugby
S. Gray
Jo. Kempenaar
R. Krylo
E. Valdes (LW)

353J
SPACECRAFT THERMAL ENGINEERING
Nickolas Emis

C. Bertagne (ECH)
D. Forgette
J. Kanis
R. Lee
A. Mastropietro
J. Miller
K. Novak
A. Paris
S. Reilly
T. Schmidt (ECH)
J. Villalvazo
P. Wu

353K
THERMAL FLUID SYSTEMS AND MISSION OPERATIONS
Gordon C. Cucullu

K. Anderson (FPT)
D. Bame (IEP)
D. Berisford
B. Carroll
M. Chainyk
B. Furst (ECH)
R. Higuera
P. Karlmann
W. Ledeboer
E. Maghsoudi (ECH)
M. Pauken (GL)
K. Singh (ECH)
L. Tse (ECH)
M. Wagner (ECH)
D. Zayas

353L
PROPULSION AND FLUID FLIGHT SYSTEMS
David A. Vaughan

M. DeVost (ECH)
E. Jens
A. Karp
M. Klatte
R. Lam
J. R. Lewis
J. Mueller
B. Nakazono
J. Paredes Garcia (ECH)
J. Parker

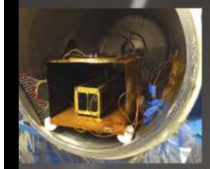
353M
CHEMICAL PROPULSION SYSTEMS
Arturo R. Casillas

T. Barber
C. Garner
J.C. Lewis
A. Mitchell
F. Picha
J. Reh (ECH)
C. Sedano
D. Turner
P. Woodmansee

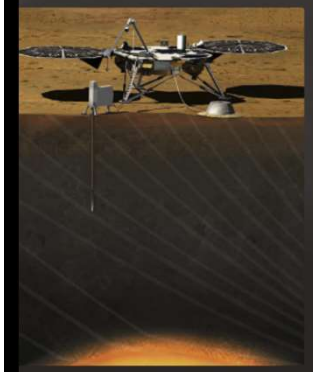
Section 3530 - Areas of Expertise

Contamination Control

We provide contamination control engineering expertise for technology development and flight projects from concept through mission end-of-life.



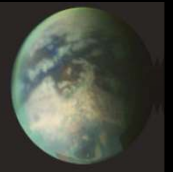
Thermal vacuum test of LMRST-Sat



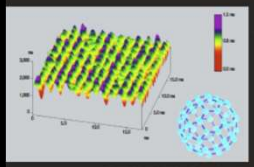
Artist's concept of InSight lander on Mars

InSight lander propulsion leak and proof testing

Analytical Chemistry



We provide excellence in chemistry-based science and engineering. We are expert users of state of the art analytical chemistry equipment critical for materials development and characterization as well as surface/contamination evaluation. We develop new geo-chemical instruments as well as develop/use Aerogel materials for both technology and flight applications.



C-60 MOLECULES: Published in SCIENCE Vol 253, 91 c60b

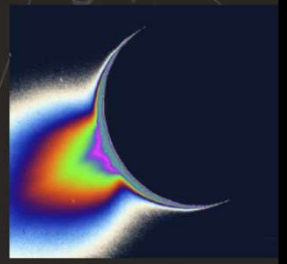


Image of Enceladus showing the fountain-like spray from the south polar region

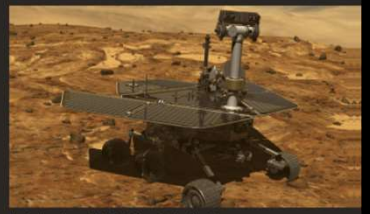
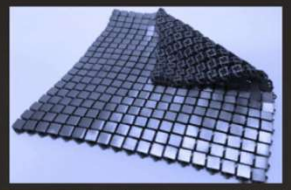


Illustration of one of the twin Mars Exploration Rovers

Materials

We provide materials engineering leadership for the design of JPL flight systems, as well as testing and evaluation of materials and assemblies for risk reduction. We also provide key support in the infusion of new materials and processes into flight projects.



Additively manufactured 3-D metallic fabric

Example of 3-D printed aircraft part

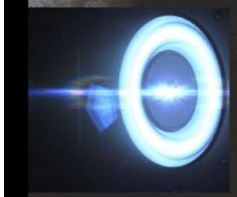
JPL-developed RoboSimian limbed robot

Gradient alloy optics mount

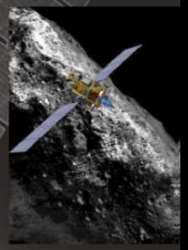
Section 3530 - Areas of Expertise (concluded)

Electric Propulsion

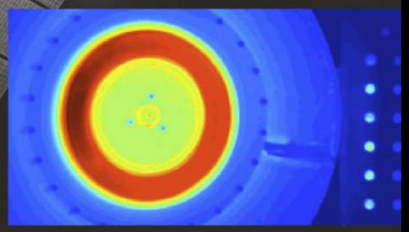
We support NASA mission needs in the area of Electric Propulsion over the full mission life cycle from technology development through flight implementation and operations. We also provide physics-based modeling and analysis expertise for technology applications and flight systems.



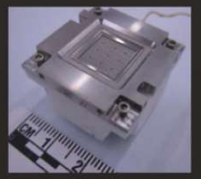
Solar electric propulsion thruster



Deep Space 1 near asteroid, artist's concept



Plume analysis for HERMeS thruster

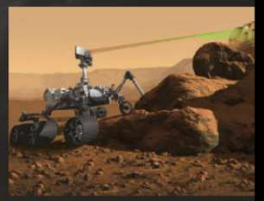


Microfluidic electrospray propulsion thruster

Chemical Propulsion

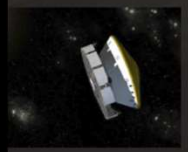
We provide Chemical Propulsion leadership, design, analysis and testing for technology and flight programs throughout the entire design cycle from concept to mission operations. We also provide advanced flow control design concepts and implementation approaches for instruments and flight experiments.

Low-Density Supersonic Decelerator (LDSD) flight test



Mars 2020 artist's concept

LDSD in test chamber

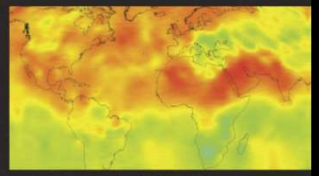


Spacecraft in its cruise phase between launch and final approach to Mars, artist's concept

Thermal Systems

We lead and support thermal systems engineering development of science instruments and spacecraft during the entire JPL project life cycle. We apply state of the art technologies and proven techniques to control temperatures of flight hardware in order to meet customer needs and achieve mission goals within available resources.

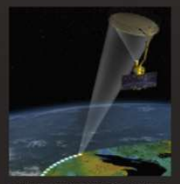
Orbiting Carbon Observatory-2 launch preparation



Orbiting Carbon Observatory-2 carbon dioxide map

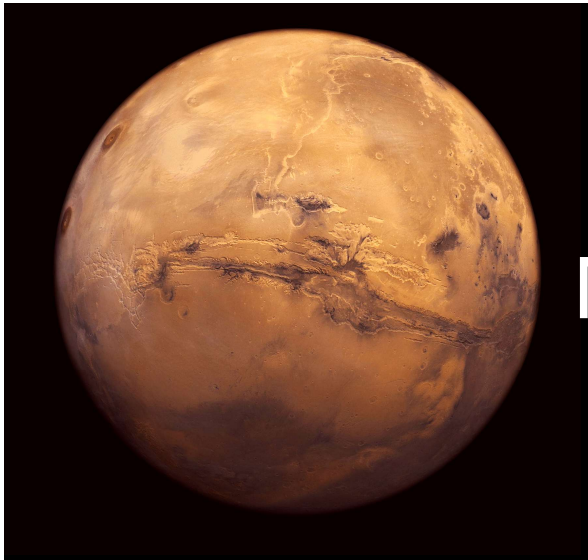
Gale Crater from Mars orbit

Mars Science Laboratory in test chamber



Artist's rendering of the Soil Moisture Active Passive (SMAP) satellite.

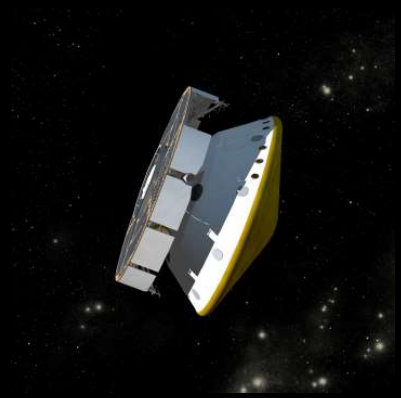
CONTAMINATION CONTROL ENGINEERING [353D]

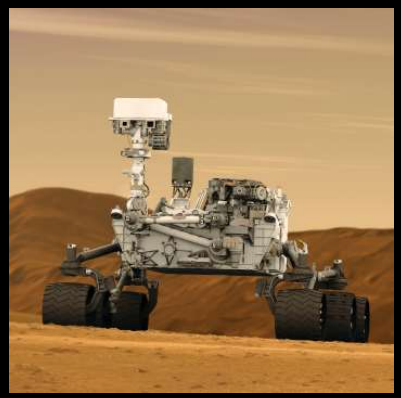


MARS MISSIONS

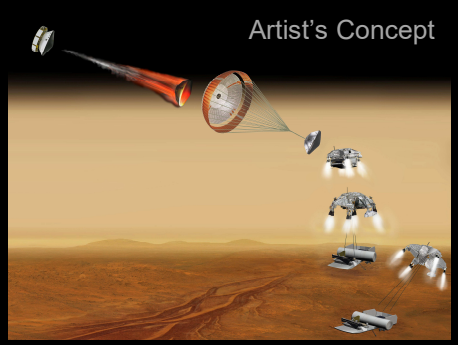
InSight [2018]

Mars 2020





Potential Mars Sample Return



Mars Orbiter Concept

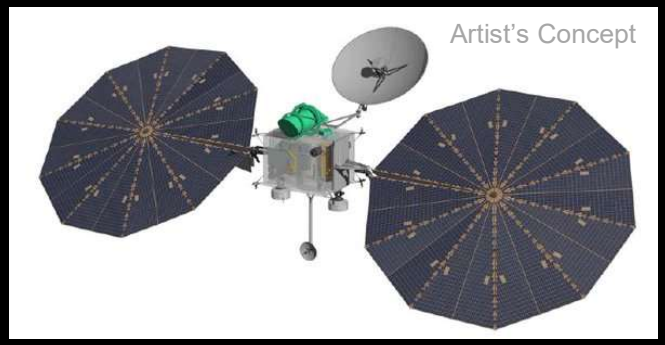
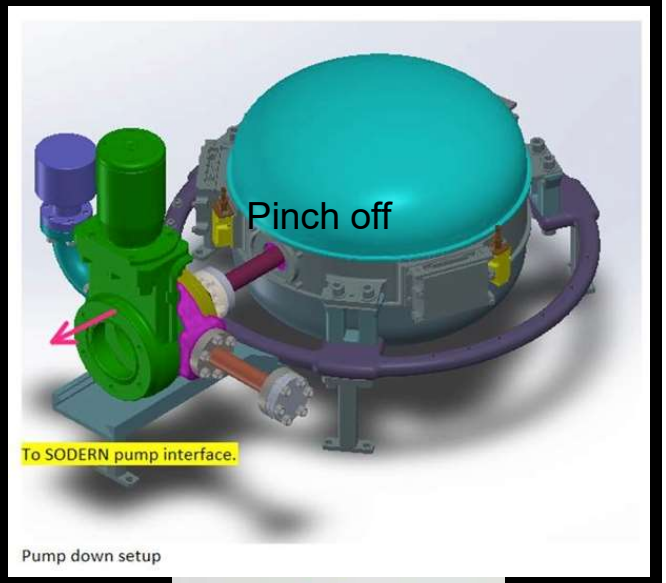


Image source: NASA/JPL

Mars InSight Lander: SEIS Instrument

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is a NASA Discovery Program mission that will place a geophysical lander on Mars to study its deep interior. Launch is scheduled for 2018.

- ***Vacuum Test Chamber System Development and fabrication***
- ***Molecular Absorber Development***
- ***Molecular Absorber Testing***
- ***Failure Analysis support***



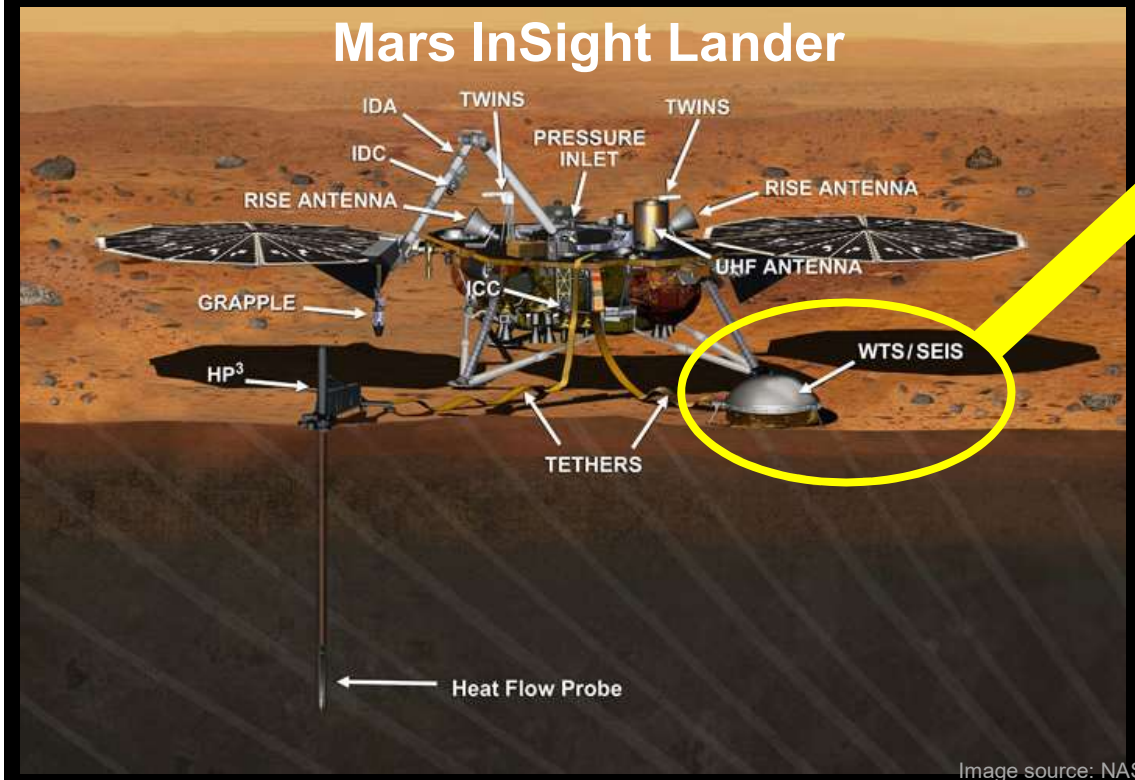
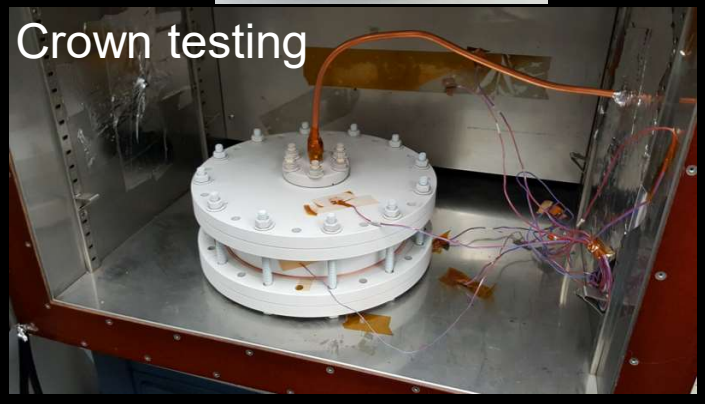


Image source: NASA/JPL

SEIS



Insight Molecular Adsorber (Getter) Development

SEIS (Seismic Experiment for Interior Structure) End-of-Life (EOL) pressure requirement: 0.1 mbar

Outgassing controls:

- *Low outgassing materials selection*
- *Extensive vacuum baking*
- *Feedthrough leakage testing*
- ***Molecular adsorbers (getters)***

Passive zeolite molecular adsorbers for the InSight SEIS are being developed and characterized Zeolite on Al foam and in aerogel are examined by SEM, tested for ambient capacity, vacuum capacity, thermal and chemical analysis and tested under environments

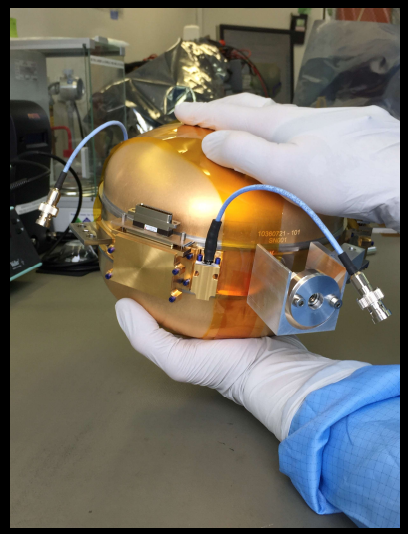
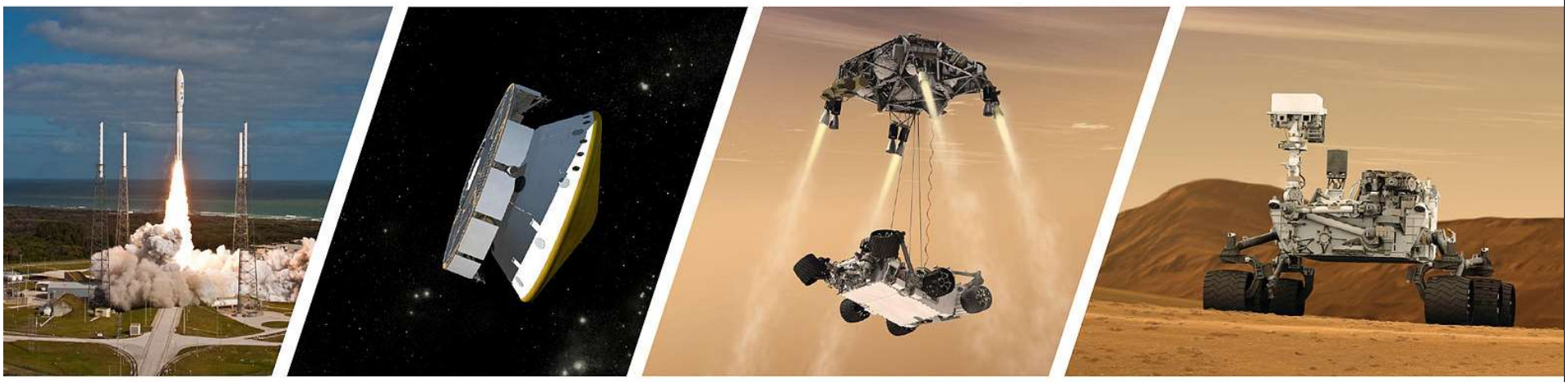


Image source: NASA/JPL

Mars 2020 Mission Timeline



LAUNCH

- Atlas V
- Period: Jul/Aug 2020

CRUISE/APPROACH

- 8 to 9-month cruise
- Arrive February 2021
- No changes from MSL (equivalent checkout capability, etc.)

ENTRY, DESCENT & LANDING

- MSL EDL system: guided entry and powered descent/Sky Crane
- 25 x 20 km landing ellipse*
- Access to landing sites ±30° latitude, ≤ 0 km elevation*
- ~950 kg rover
- Technology enhancements under consideration

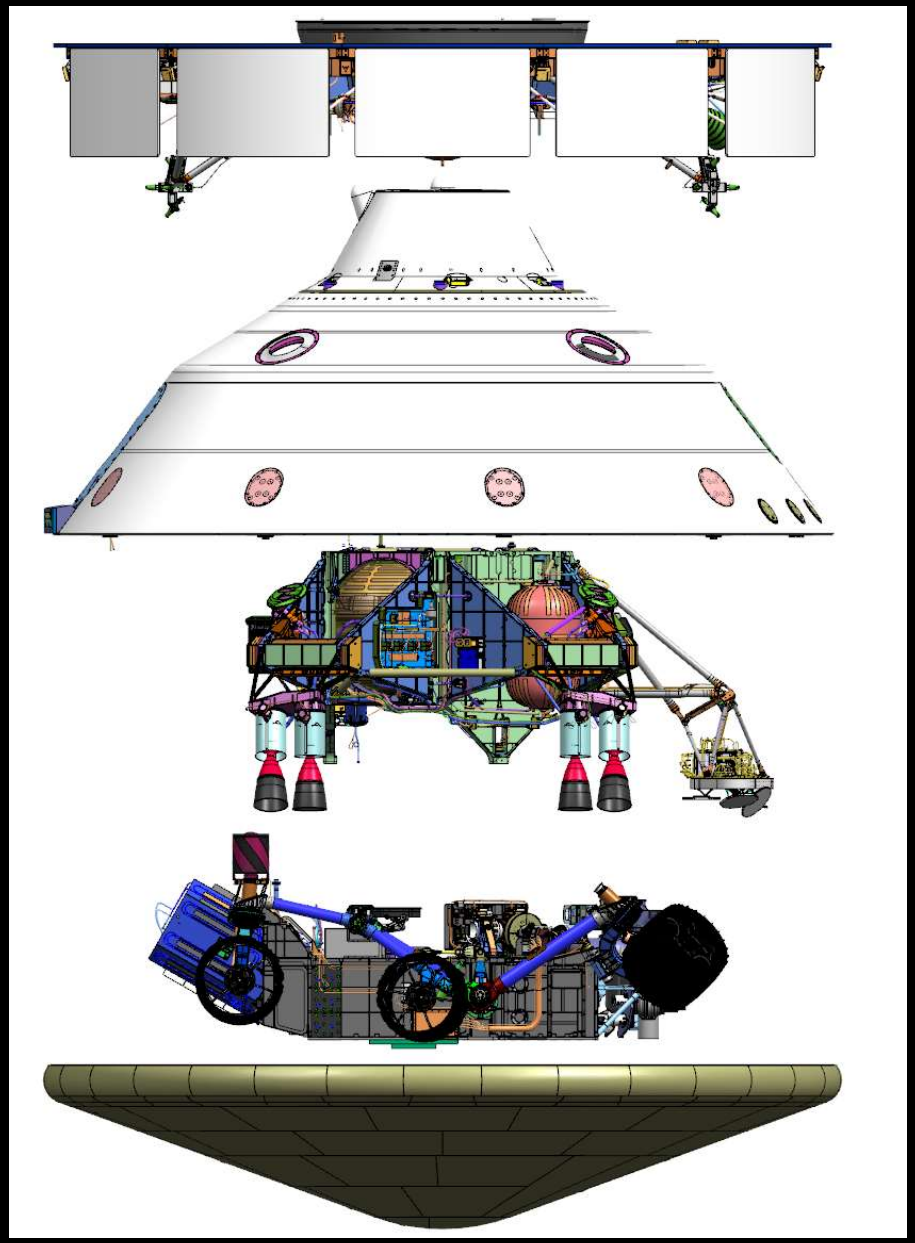
SURFACE MISSION

- Prime mission is 1.5 Mars years
- Latitude-independent and long-lived power source
- Ability to drive out of landing ellipse
- Direct (uplink/downlink) and relayed (downlink) communication
- Fast CPU and large data storage

* EDL in work

Image source: NASA/JPL

Mars 2020 Flight System



Cruise Stage:
Power, Telecom, Thermal, CEDL Mechanical, Propulsion, GN&C

New
Modified
Heritage,

Backshell / Parachute:
MEDLI2,
Telecom, Thermal, CEDL Mechanical

Descent Stage Vehicle:
Power, Telecom, Thermal, CEDL Mechanical, Propulsion, GN&C, TDS, Motion Control

Rover:
Sample Caching Assembly, EECAMs, TRN, Thermal, Rover Chassis/Harness, RSM, Mobility, Motion Control, Surface FSW, Avionics, Power, Telecom, GN&C, CEDL FSW

Heatshield:
MEDLI2,
Thermal, CEDL Mechanical

Image source: NASA/JPL

Mars 2020 Instruments / Science

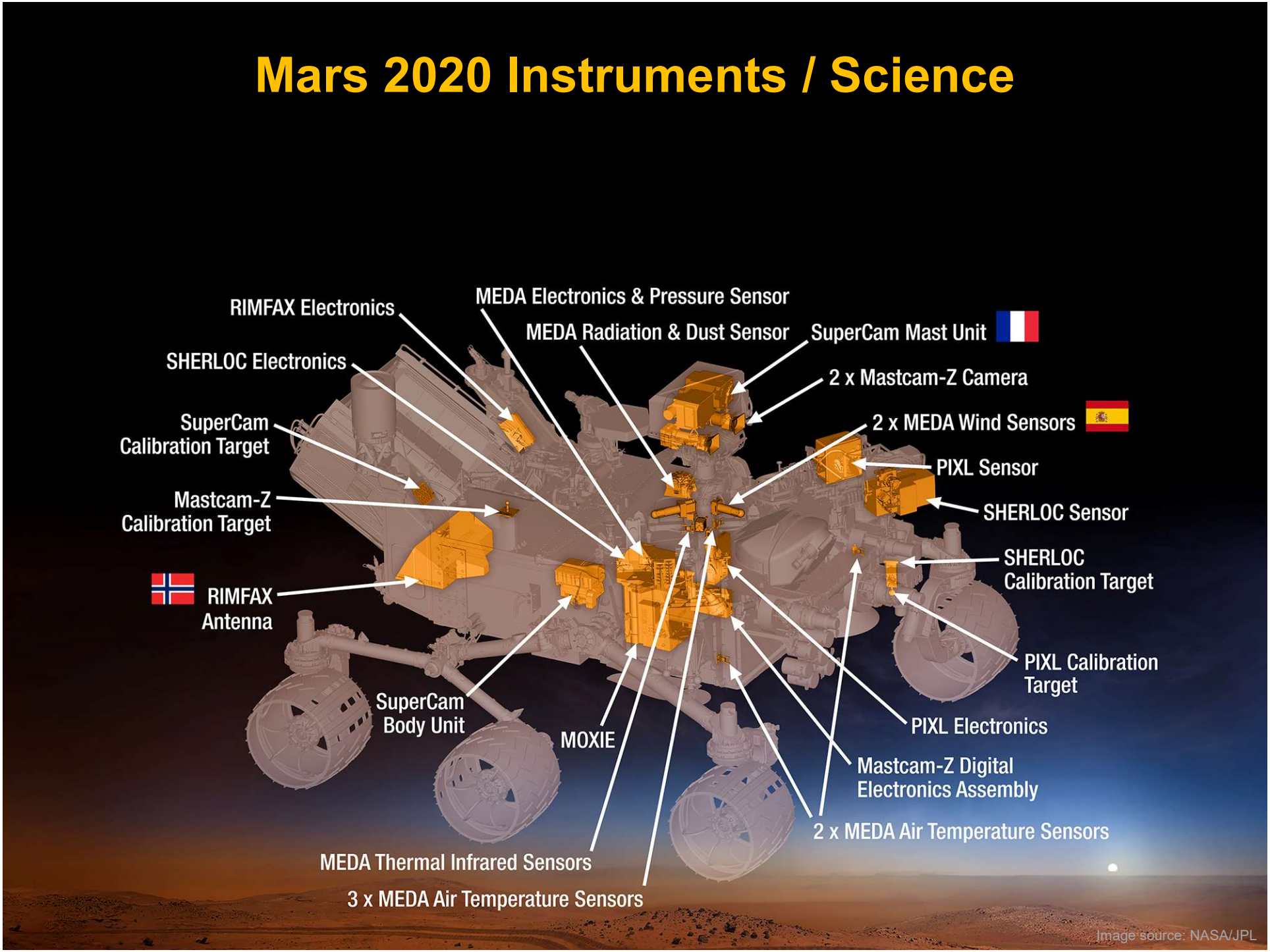
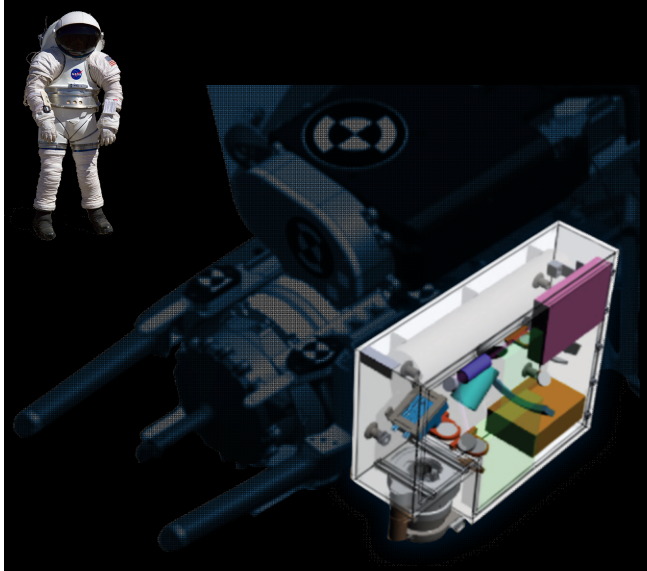


Image source: NASA/JPL

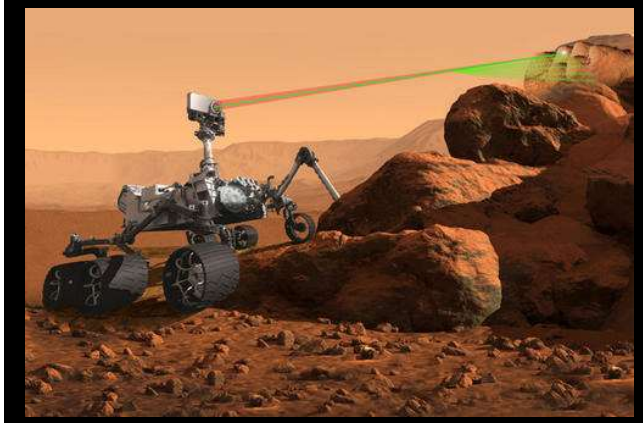
Mars 2020 Instruments / Science



Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC)

SHERLOC is an arm-mounted, Deep UV (DUV) resonance Raman and fluorescence spectrometer utilizing a 248.6-nm DUV laser and <100 micron spot size. The laser is integrated to an autofocusing/scanning optical system, and co-boresighted to a context imager with a spatial resolution of 30 µm.

SHERLOC enables non-contact, spatially resolved, and highly sensitivity detection and characterization of organics and minerals in the Martian surface and near subsurface. The instrument goals are to assess past aqueous history, detect the presence and preservation of potential biosignatures, and to support selection of return samples.



SuperCam [MSL ChemCam successor]

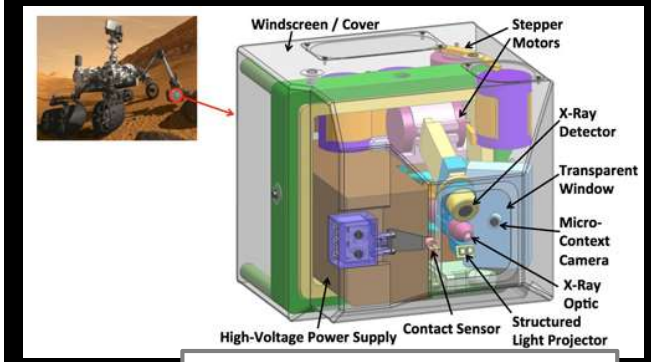
SuperCam is a remote-sensing instrument that uses remote optical measurements and laser spectroscopy to determine fine-scale mineralogy, chemistry, and atomic and molecular composition of samples encountered on Mars. It integrates the remote Laser Induced Breakdown Spectroscopy (LIBS) capabilities of the ChemCam instrument. LIBS uses a 1064-nm laser to investigate targets up to 7 m distance from the rover.

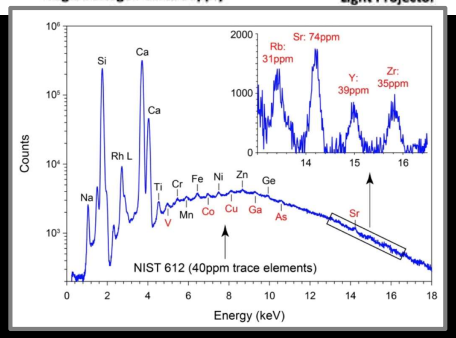
SuperCam can perform Raman spectroscopy (at 532 nm to investigate targets up to 12 m distance), Time-Resolved Fluorescence (TRF) spectroscopy, Visible and InfraRed (VISIR) reflectance spectroscopy (400 – 900 nm, 1.3 – 2.6 µm) at a distance, as well as being able to search directly for organic materials.

SuperCam also acquires high-resolution images of samples under study using a color remote micro-imager (RMI).

Image source: NASA/JPL

Mars 2020 Instruments / Science (cont.)

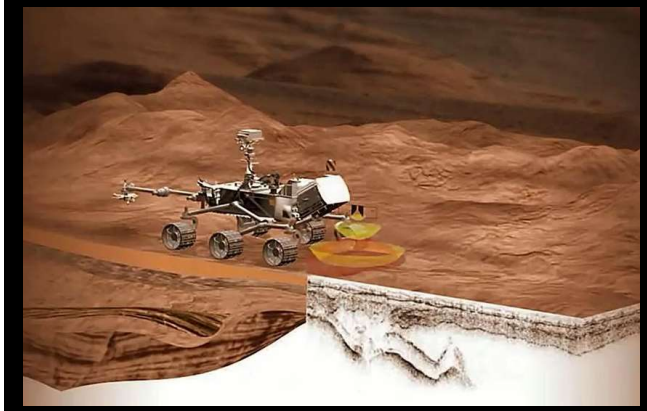




Planetary Instrument for X-ray Lithochemistry (PIXL)

PIXL is a microfocus X-ray fluorescence instrument that measures elemental chemistry at sub-millimeter scales by focusing an X-ray beam to a tiny spot on the target rock or soil and analyzing the induced X-ray fluorescence.

The sensor head includes an x-ray source, X-ray optics, X-ray detectors, and high-voltage power supply (HVPS), as well as a micro-context camera (MCC) and light-emitting diode (LED). PIXL can detect over 26 elements (Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Br, Rb, Sr, Y, Ga, Ge, As, and Zr, with important trace elements such as Rb, Sr, Y and Zr) detectable at a level of 10's ppm.



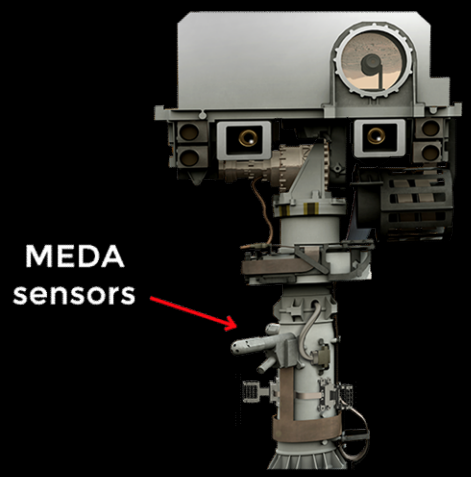
Radar Imager for Mars' subsurFAce eXperiment (RIMFAX)

RIMFAX is ground-penetrating radar (GPR) instrument designed to produce high-resolution stratigraphic information about the subsurface of Mars.

It is based on an ultra wideband design, operating from 150 MHz to 1.2 GHz, with a theoretical limit of 14.2 cm for vertical resolution in free-space. The objective of RIMFAX is to image the subsurface structure and constrain the nature of the material underlying the landing site. The propagation of radar waves is sensitive to the dielectric properties of materials, such that variations in composition and porosity across geologic strata yield radar reflections that can be identified, mapped, and interpreted in the geological sense.

Image source: NASA/JPL

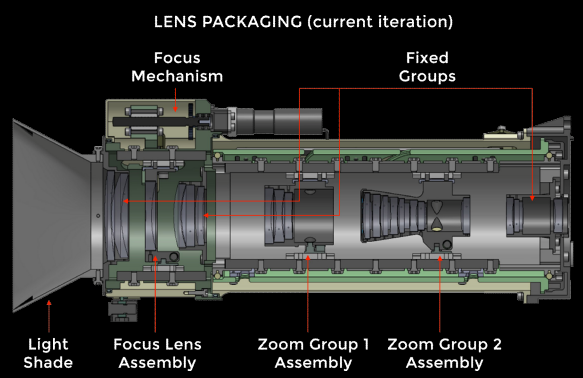
Mars 2020 Instruments / Science (concluded)



Mars Environmental Dynamics Analyzer (MEDA)

MEDA is a suite of environmental sensors designed to record dust optical properties and six atmospheric parameters: wind speed/direction, pressure, relative humidity, air temperature, ground temperature, and radiation in discrete bands of the UV, visible, and IR ranges of the spectrum.

The radiation sensor is part of an assembly with two arrays of photodiodes that also capture low elevation angle scattered light and a sky-pointing camera; these data are combined to characterize the properties of atmospheric aerosols.



Mastcam-z [New lens design]

Mastcam-Z is a multispectral, stereoscopic imaging instrument based on the Mastcam instrument on the Curiosity rover.

It has mast-mounted cameras that can zoom in, focus, and take 3-D pictures and video at high speed to allow detailed examination of distant objects.

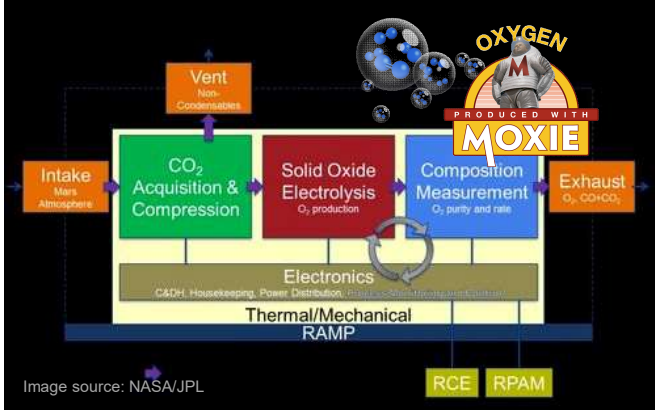


Image source: NASA/JPL

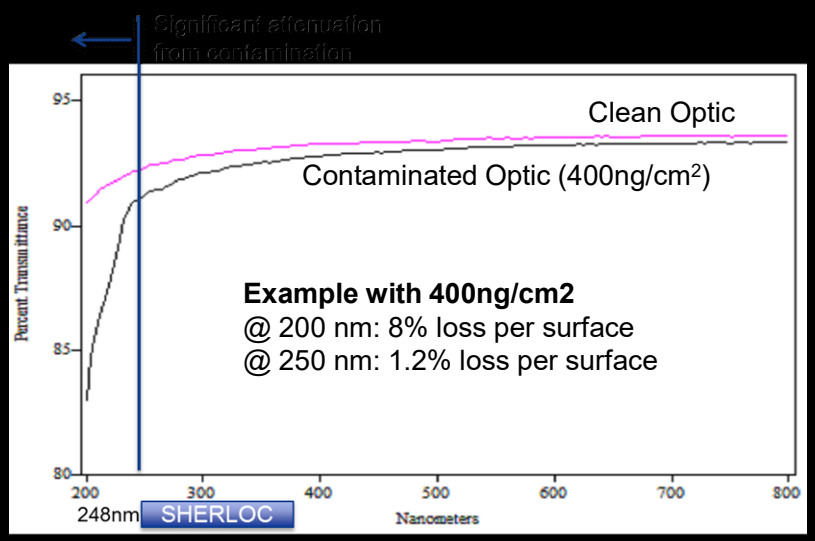
Mars Oxygen ISRU Experiment (MOXIE)

In preparation for the human exploration of Mars, the objectives of the MOXIE investigation on the Mars 2020 mission include:

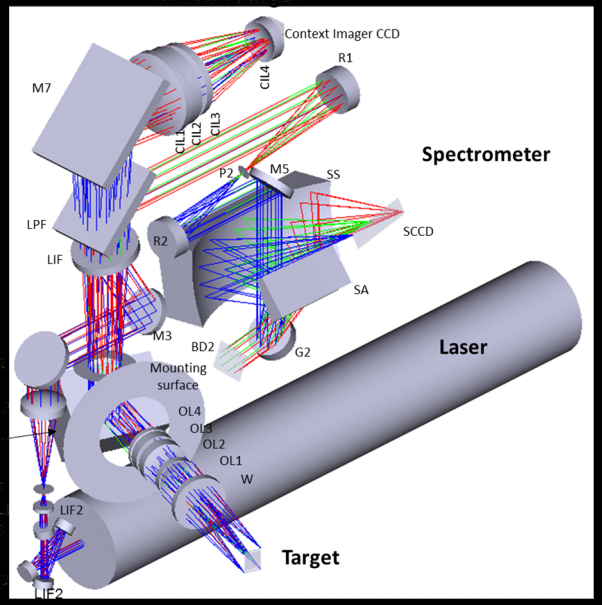
- demonstration of In-Situ Resource Utilization (ISRU) technologies to enable propellant and consumable oxygen production from the Martian atmosphere, and
- characterization of atmospheric dust size and morphology to understand its effects on the operation of surface systems.

Special Considerations
Mars 2020 Instruments with UV & Raman

- Two Mars 2020 Payload Instruments will have capability to perform UV Fluorescence and Raman spectroscopy
- The SHERLOC Instrument a deep UV fluorescence and Raman system
  - Includes a deep UV laser source (248.5 nm)
  - Spectrometer with a UV spectral range of 250 to 354nm
  - Visible imager (500-600nm)

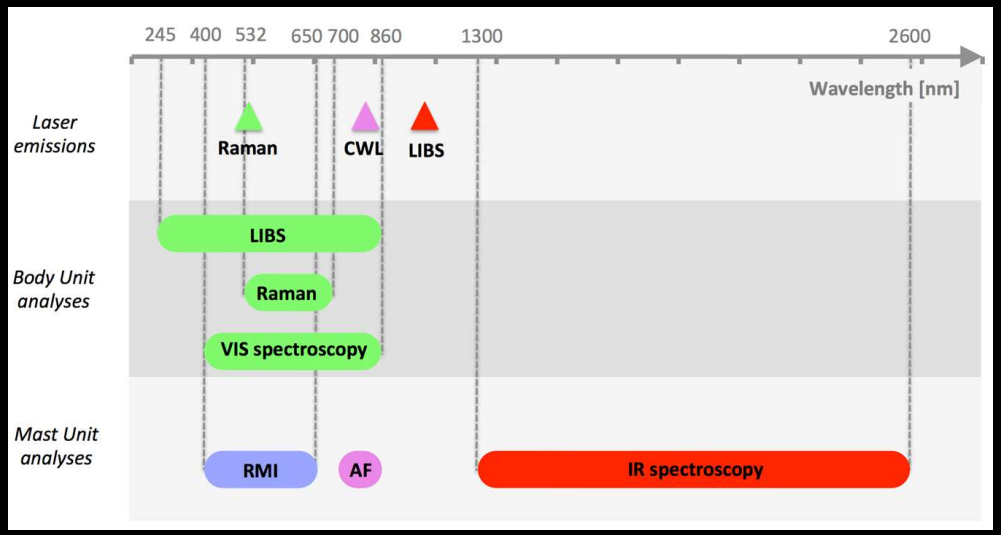


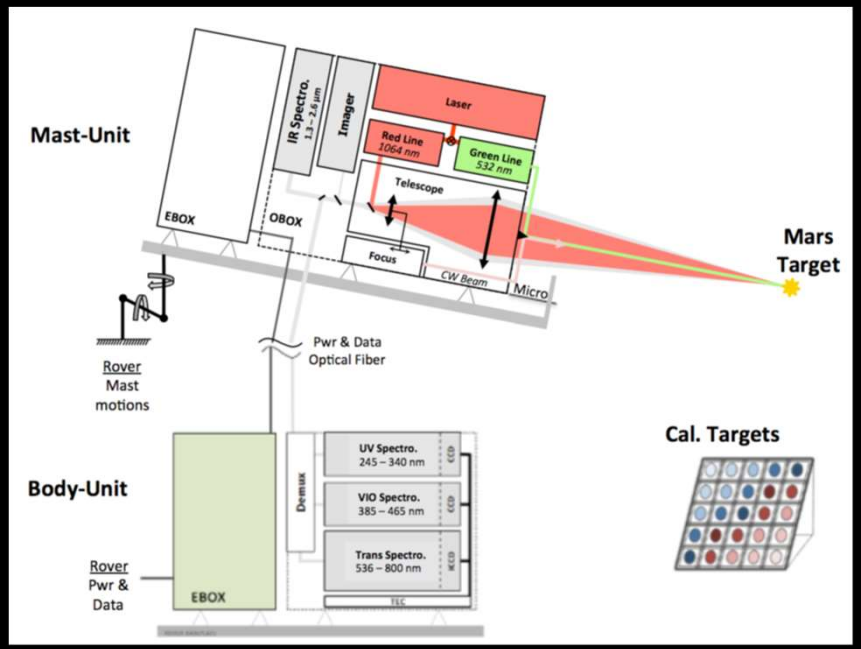
G2 = spectrometer grating
P1 = laser pin hole
P2 = spectrometer slit
R1 = relay OAP 1
R2 = relay OAP 2
BEL1 = beam expander lens 1
BEL2 = beam expander lens 2
W = window
BS = beam splitter
AS = aperture stop
SA = spectrometer asphere
SS = spectrometer sphere
OL1-4 = objective lens 1-4
CIL1-4 = context imager lens 1-4
LIF = laser injection filter
LIF2 = laser injection filters
LPF = long pass filter
M7 = notch filter
BD2 = spectrometer beam dump



Special Considerations
Mars 2020 Instruments with UV & Raman

- The SuperCam Instrument integrates a Laser Induced Breakdown Spectroscopy (LIBS) (1064 nm Laser), Raman (532 nm Laser) and VISIR Reflectance Spectrometry Instrument
  - Includes a Laser source (Red Line 1064 nm, Green Line 532 nm)
  - UV Spectrometer (245 nm- 340 nm)
  - VIO Spectrometer (385 nm – 465 nm)
  - Transmission Spectrometer (536 nm – 800 nm)
  - IR Spectrometer (1300 nm – 2600 nm)

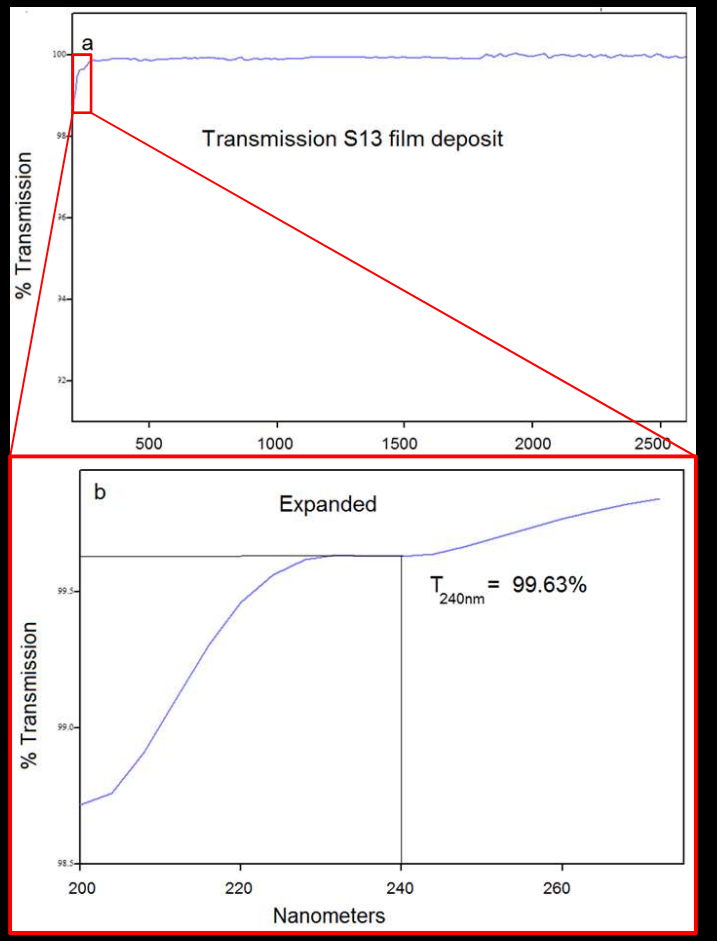




Special Considerations
UV – RAMAN Contamination Control Summary

Contamination which fluoresces is of special concern for UV – Raman Spectroscopy

- Fluorescence is much stronger than Raman (10^6 to 10^8 times stronger) and it overwhelms the Raman signal
- Fluorescent contamination deposited onto instrument optics will attenuate the signal resulting in significant transmission loss
- Aromatic organics fluoresce
- Different organic materials will have different attenuations in the UV
  - A very small deposition onto a sensitive optic can have a major impact
  - Evaluating Mars rover materials for fluorescence is a major challenge (large number of materials)



Mars 2020 Contamination Control Activities

Model Development

Particle transport code has been developed and updated to incorporate effects of ultraviolet radiation.
Code is being extended to track particle transport between rover surfaces.

Experimental Work

Flow chamber experiments to characterize particle adhesion and detachment are in progress.

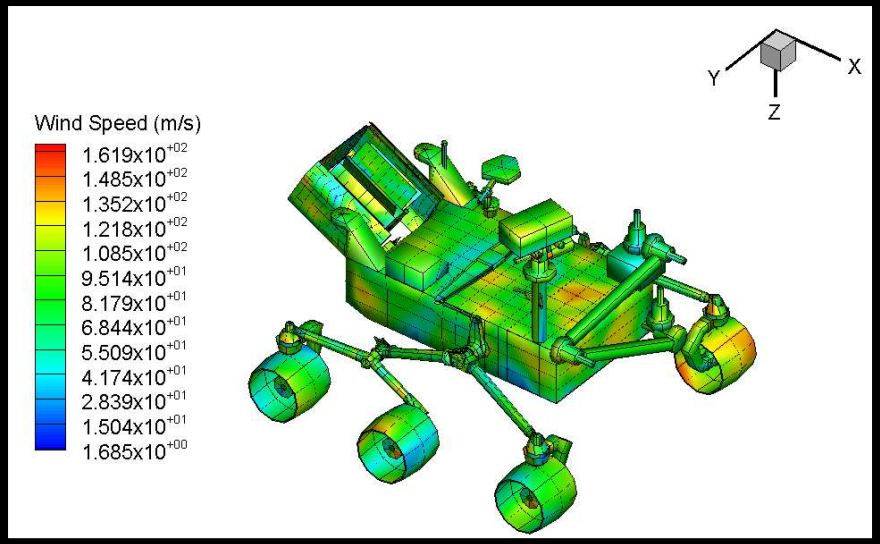
Materials

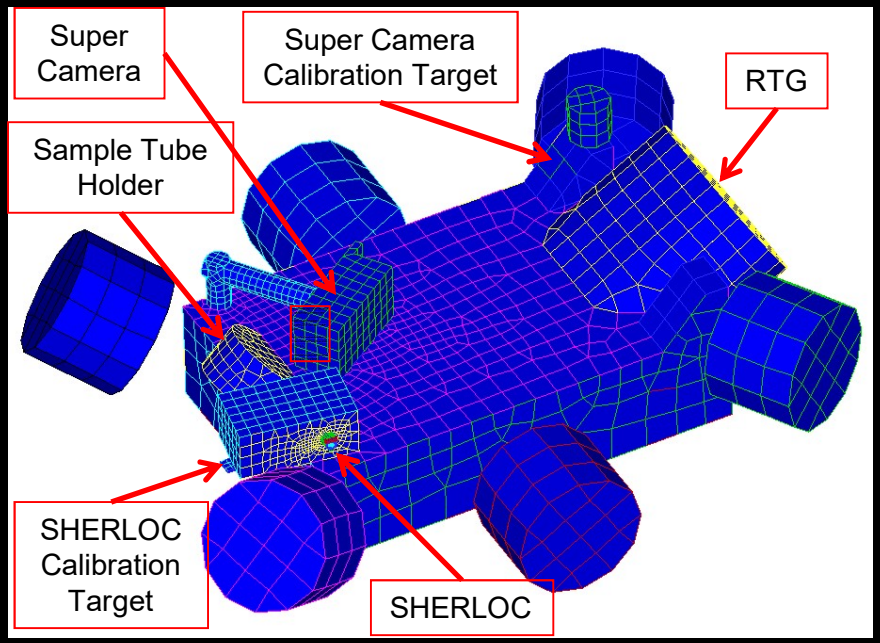
Ultra-Low Outgassing Silicones

SCV-2585 ultra-low outgassing (ULO) RTV has been tested, analyzed and approved for use on the SHERLOC instrument.
Use of ULO RTV in place of heritage materials is being evaluated for use in EECAM, PIXL and SuperCam.

S13GP:6N/LO-1 low-outgassing

Use of S13GP:6N/LO-1 low-outgassing silicone paint (vacuum baked) for use in sensitive instruments has been approved by Contamination Control Engineering.





Mars 2020 Contamination Control Activities

Mars 2020 Sample Cache Tube Trace Organic Analysis

Sample caching requires ultra-clean hardware

- *Contamination Mitigation Studies*
- *Ultra-trace Chemical Analysis Method Development*
- *Surface Analysis of Critical Hardware*
- *Low Surface Energy Materials development*

https://www.youtube.com/watch?v=cf47bvULtEQ

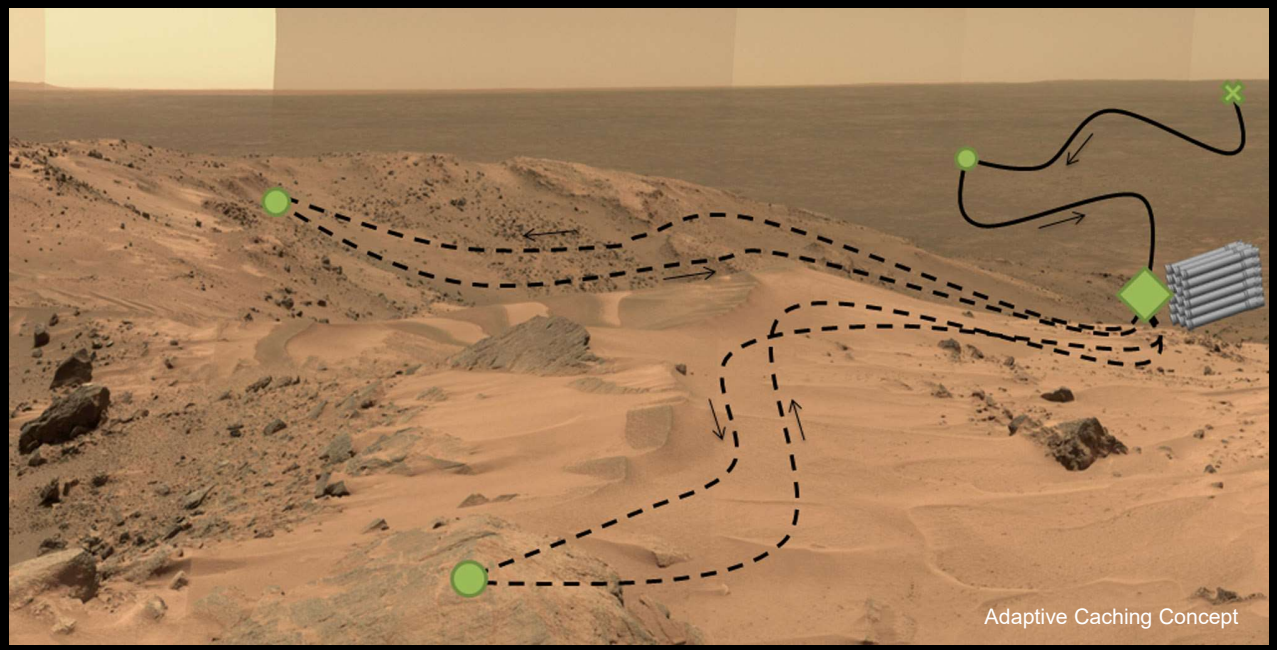


Image source: NASA/JPL

Planetary Protection Mission Categories

Types of Mars Missions	Mission Type	Mission Category
Lander systems not carrying instruments for the investigations of extant Mars Life.	Lander, Probe	IVa
Lander systems designed to investigate extant Martian Life.	Lander, Probe	IVb
Missions investigating Martian Special Regions, even if they do not include life detection experiments. Martian Special Regions include those within which terrestrial organisms are likely to replicate and those potentially harboring extant Martian Life.	Lander, Probe	IVc

Planetary Targets/Locations	Mission Type	Mission Category
Undifferentiated, metamorphosed asteroids; Io; others TBD.	Flyby, Orbiter, Lander	I
Venus; Earth's Moon; Comets; non-Category I Asteroids; Jupiter; Jovian Satellites (except Io and Europa); Saturn; Saturnian Satellites (except Titan and Enceladus); Uranus; Uranian Satellites; Neptune; Neptunian Satellites (except Triton); Kuiper-Belt Objects (< 1/2 the size of Pluto); others TBD.	Flyby, Orbiter, Lander	II
Icy satellites, where there is a remote potential for contamination of the liquid-water environments, such as Ganymede (Jupiter); Titan (Saturn); Triton, Pluto and Charon (Neptune); others TBD.	Flyby, Orbiter, Lander	II*
Mars; Europa; Enceladus; others TBD (Categories IVa-c are for Mars).	Flyby, Orbiter	III
	Lander, Probe	IV(a-c)
Venus, Moon; others TBD: "unrestricted Earth return"	unrestricted Earth-Return	V (unrestricted)
Mars; Europa; Enceladus; others TBD: "restricted Earth return"	restricted Earth-Return	V (restricted)

https://planetaryprotection.nasa.gov

Planetary Protection NPR 8020.12D

Section 5.3.2.2

Caching hardware involved in acquisition, delivery, and storage of samples intended for Earth return shall be

- Cleaned to a level of <300 heat resistant 'spores'/m^2,
- Enclosed in a physical biobarrier,
- And subjected to a validated bioburden reduction process that achieves at least 4-orders of magnitude of microbial reduction.

The physical biobarrier that prevents recontamination shall not be opened until operations at Mars.

Example acceptable contamination limits while conducting operations on Mars include:

- <1 viable Earth organism per cached sample,
- 100 ppb TOC baseline (Tier 1 & 2 compounds),
- And 40 ppb TOC threshold (Tier 1 & 2 compounds).

Section 5.3.3.2

The M2020 project shall ensure that Mars samples intended for possible future return are not contaminated by terrestrial organic compounds or viable organisms at levels above those specified below, through final deposition of sample tubes on Mars:

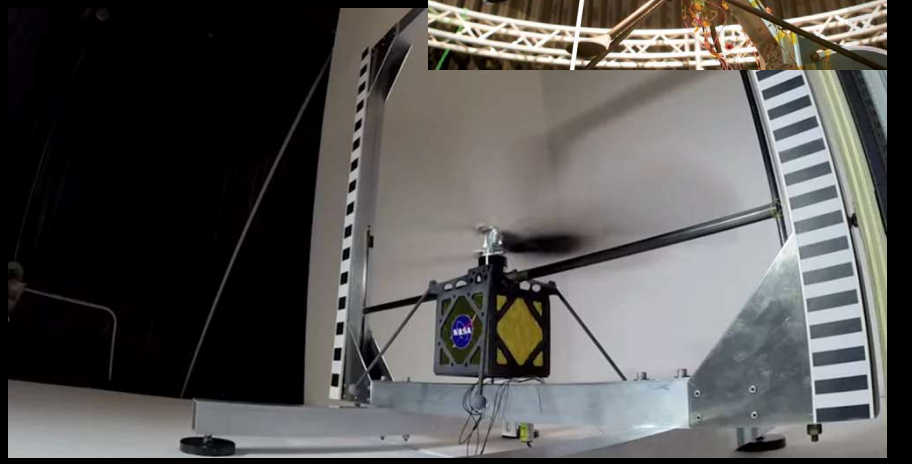
- The probability that a single viable organism is introduced into each sample shall be less than the limit obtained by multiplying the internal surface area of a sealed sample tube, in m^2, by the Viking post-sterilization surface bioburden limit of 0.03 viable organisms per m^2,
- Terrestrial organic contamination shall be limited to levels below <1 ppb of any Tier 1 organic compound per sample; <10 ppb Total Organic Carbon per sample,
- And sample tubes shall be designed for opening after return to Earth in a manner that prevents additional contamination of samples during extraction.

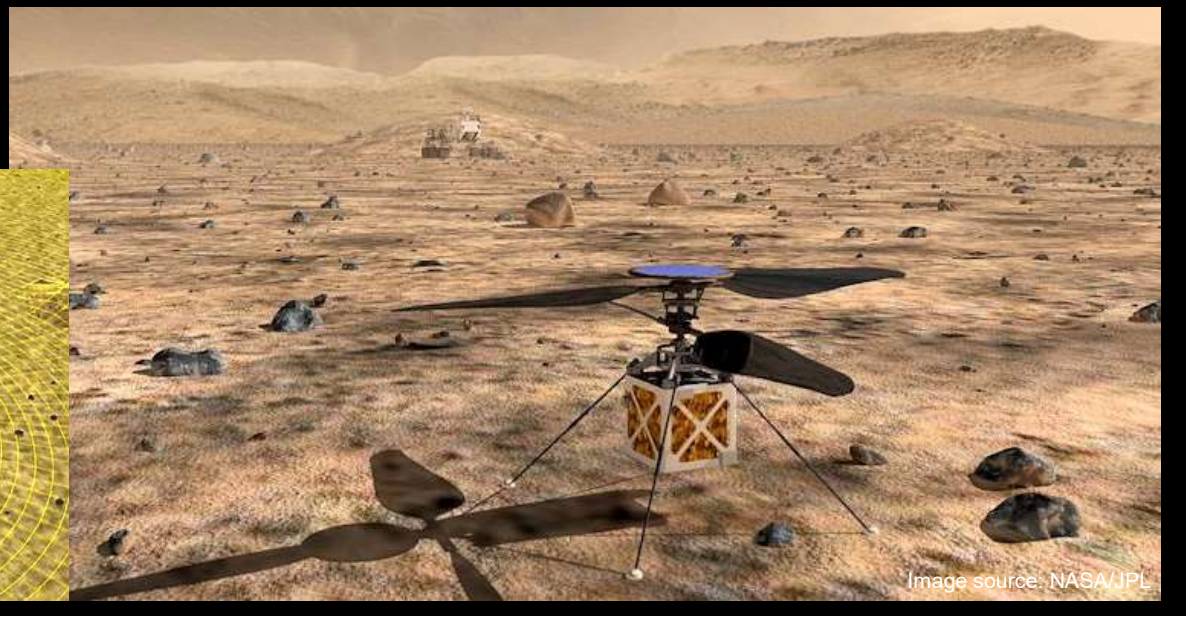
https://planetaryprotection.nasa.gov

Proposed Mars Helicopter

https://www.youtube.com/watch?v=vpBsFzjyRO8

The Mars helicopter is a lightweight robotic helicopter with an upper limit of 1 Kg (2.2 lbs) and a pair of counter-rotating blades spanning 1.1 m (2.6 ft). The blade span is large being designed for operation in a 7 Torr CO_2 atmosphere of Mars.
The Mars helicopter would be solar powered. The solar panel would supply enough electricity for repeated takeoffs and landing with an endurance of 2 to 3 minutes of flight per Martian day for a distance of 500 m (1,640 ft). Tethered flight tests are being conducted under a 7 Torr CO_2 atmosphere at the large 25-ft Space Simulator at JPL (Environmental Test Facility).

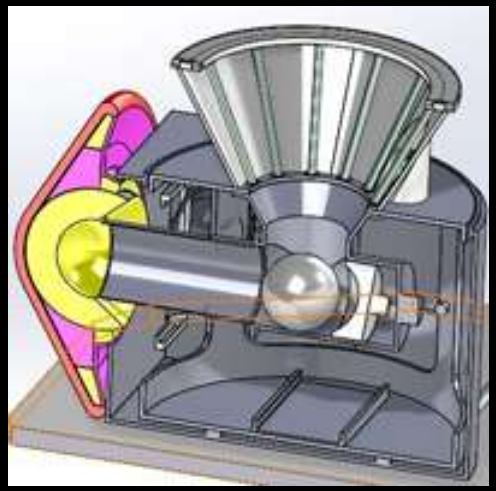




Potential Mars Sample Return
Advanced Technology Development

Current advanced technology development for a potential robotic Mars Sample Return (MSR) architecture could involve a campaign of three missions:

- MSR-C (fulfilled by Mars 2020) will collect and cache samples with a rover
- MSR-L mission concept would retrieve the Cache Canister and launch it into Mars orbit using a lander, rover and a Mars Ascent Vehicle (MAV)
- MSR-O mission concept would locate and capture the Orbital Sample (OS) in Mars orbit and return it to Earth



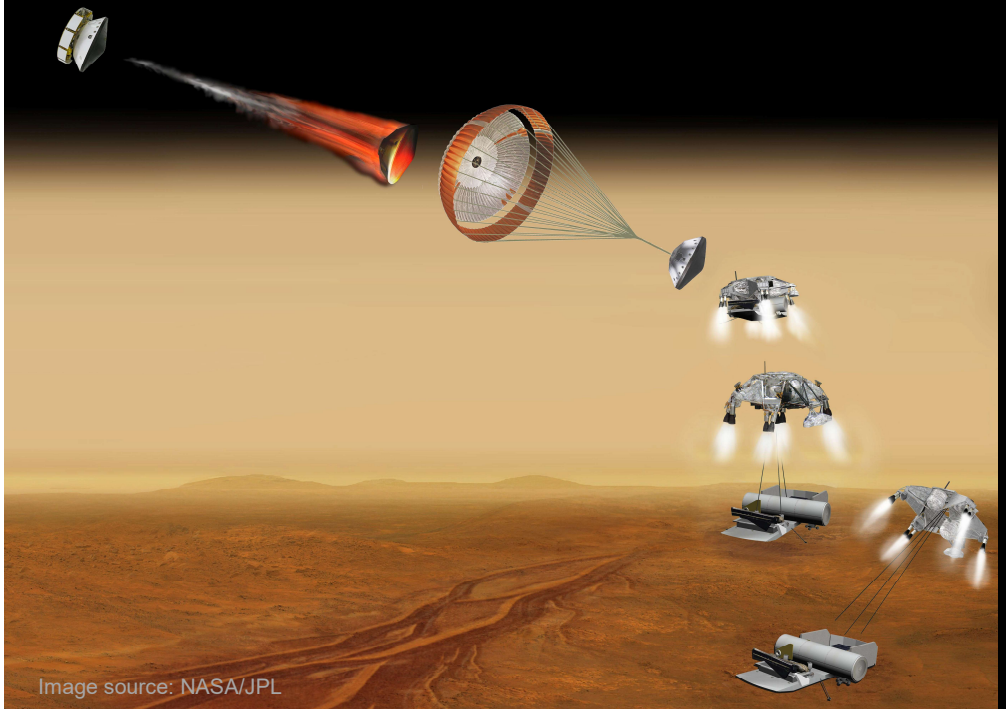
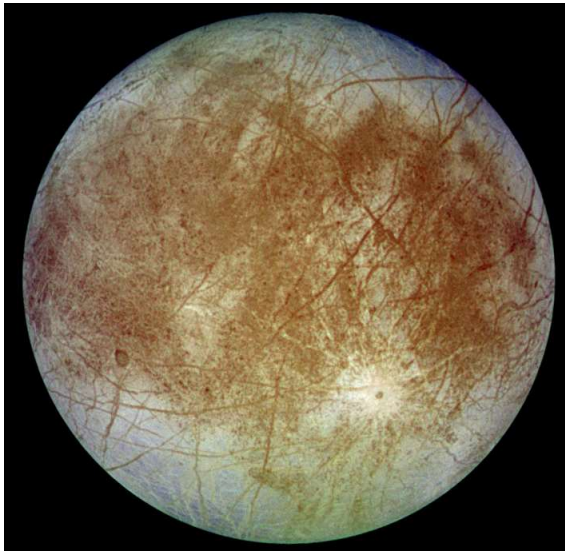
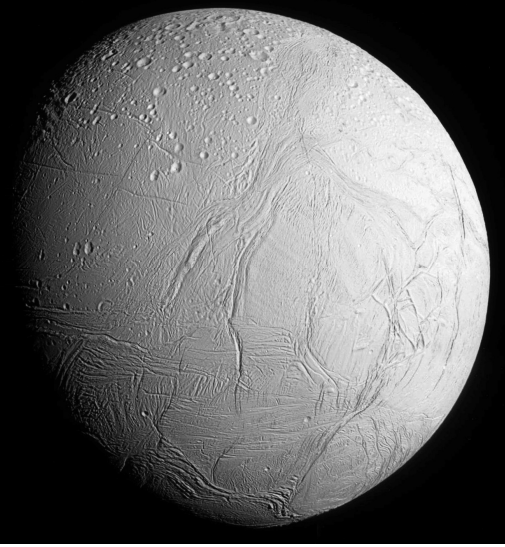


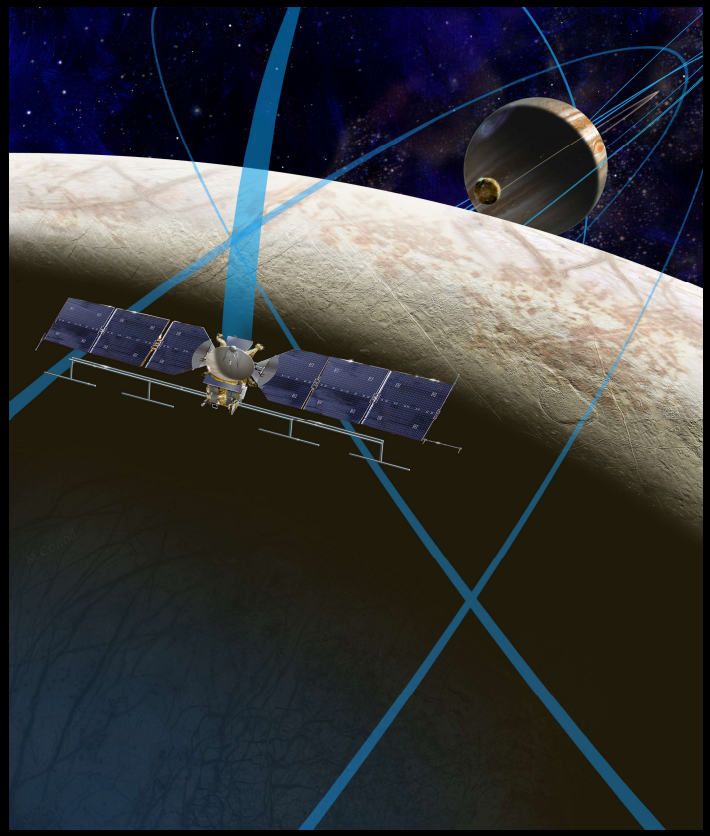
Image source: NASA/JPL



ICY MOONS



Europa



Enceladus

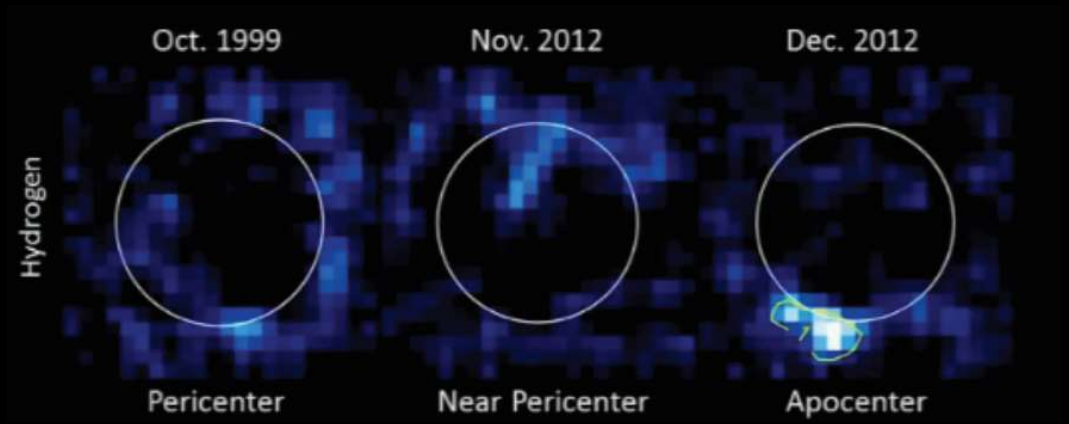
Artist's Concept: NASA/JPL

Proposed Europa Missions

Europa Mission (Orbiter)

Mission in Phase B – Preliminary Design

- *Orbiter would have a high-sensitivity mass spectrometer to measure composition of Europa plumes.*
- *Modeling interactions of Europa plumes with orbiter thruster plumes and materials outgassing.*
- *Modeling plume induced contamination of the science site on the surface of Europa*



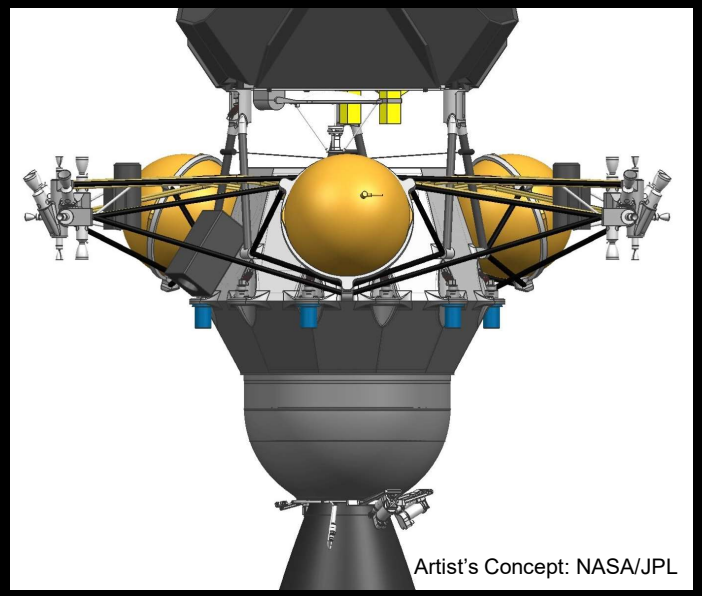
Hubble Ultraviolet images showing signs of plumes near Europa's south pole. [visible-light image of Europa has been added as a visual aid]

Image source: NASA/JPL

Europa Lander

Mission in Phase A
Mission Concept Review (MCR) in March 2017
Currently in design iteration 3.0, soon to baseline iteration 4.0 for the MCR.

- *Modeling thruster plume induced contamination of the science site on the surface of Europa*

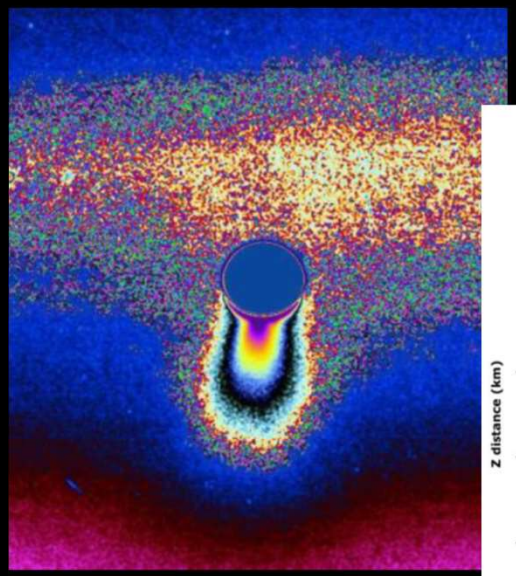


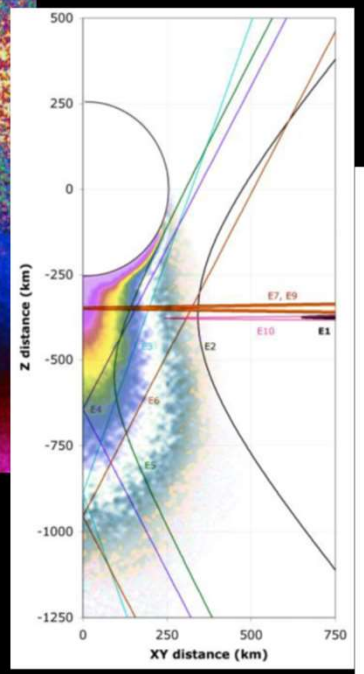
Artist's Concept: NASA/JPL

Enceladus

Plume and Jet modeling

Cassini data has been used to develop an engineering model of the Enceladus plume density, as a function of flyby altitude. These methodologies are being applied to modeling low altitude Enceladus flybys in future mission concepts.





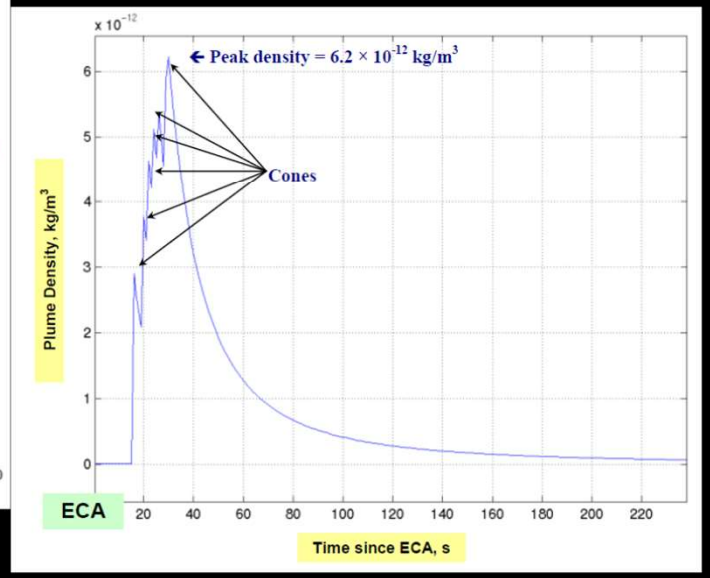
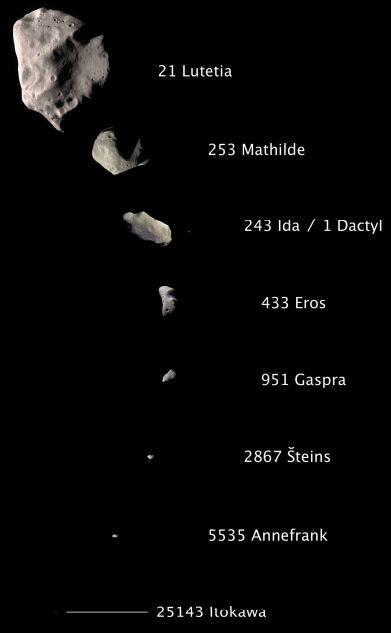


Image source: NASA/JPL

Reference: Sarani, S., *"Enceladus Plume Density Modeling and Reconstructions for Cassini Attitude Control System,"* AIAA 2010-2035, April 2010.

ASTEROIDS

4 Vesta



Concept Asteroid Robotic Redirect Mission (ARRM)

Concept: Psyche

Artists' Concept: NASA/JPL

Asteroid Redirect Robotic Mission (ARRM)

https://www.youtube.com/watch?v=3UkEximY6Ic

The robotic segment of ARM would travel to a near-Earth asteroid demonstrating:

- Advanced, high-power, high-throughput solar electric propulsion
- Advanced autonomous precision proximity operations at a low-gravity planetary body
- Controlled touchdown and liftoff with a multi-ton mass

The crew segment of the mission (Proving Ground Mission) would include spacewalk activities for sample selection, extraction, containment and return; and mission operations of integrated robotic and crewed vehicle stack.

Both segments are key components of future in-space operations for human missions to the Mars system.

Target asteroids are fewer than 121 million miles (1.3 AU) from the Sun at the closest point in their orbit. The 2008 EV5 asteroid is currently being used in mission studies because it is a primitive, C-type (carbonaceous) asteroid, possibly rich in volatiles, water and organic compounds.

Artists' Concept: NASA/JPL

The Hall Effect Rocket with Magnetic Shielding (**HERMeS**) is a 12.5 kW Hall thruster being developed by JPL and NASA/GRC for the Asteroid Redirect Robotic Mission (ARRM)

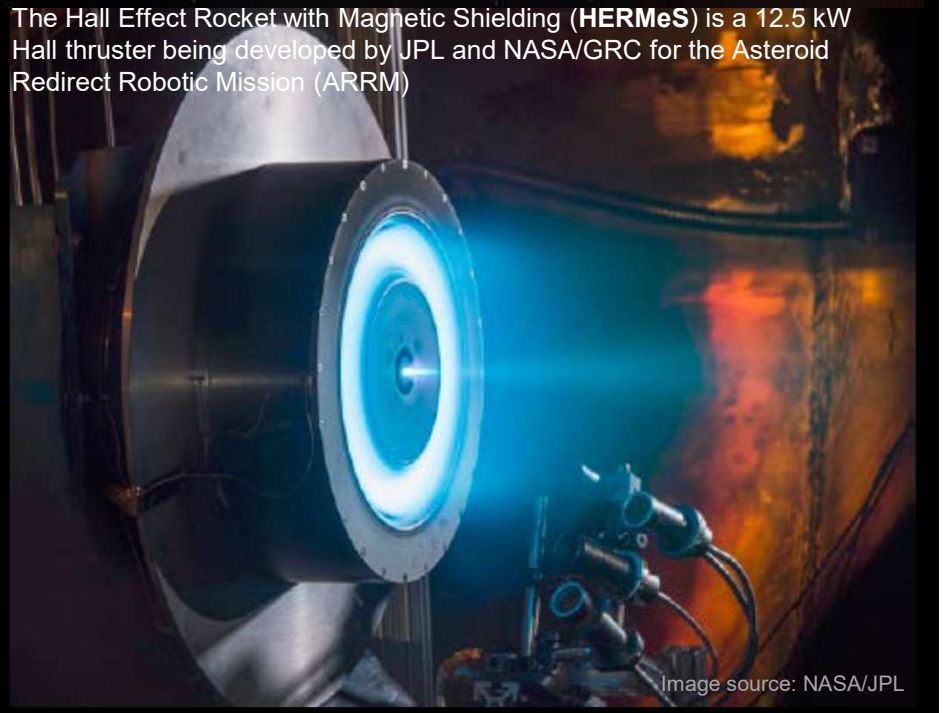
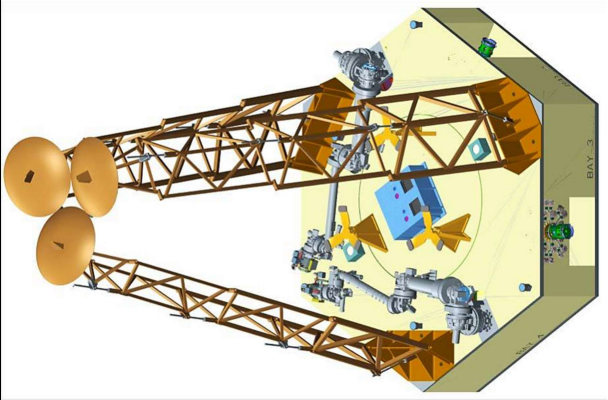


Image source: NASA/JPL

Asteroid Redirect Robotic Mission (ARRM)

Mission operations of integrated robotic and crewed (Proving Ground) vehicle stack.

- Plume induced contamination during proximity operations, docking and separation
- Materials outgassing induced contamination (docked phase)
- Contamination control during EVA activity, sample extraction, containment and return



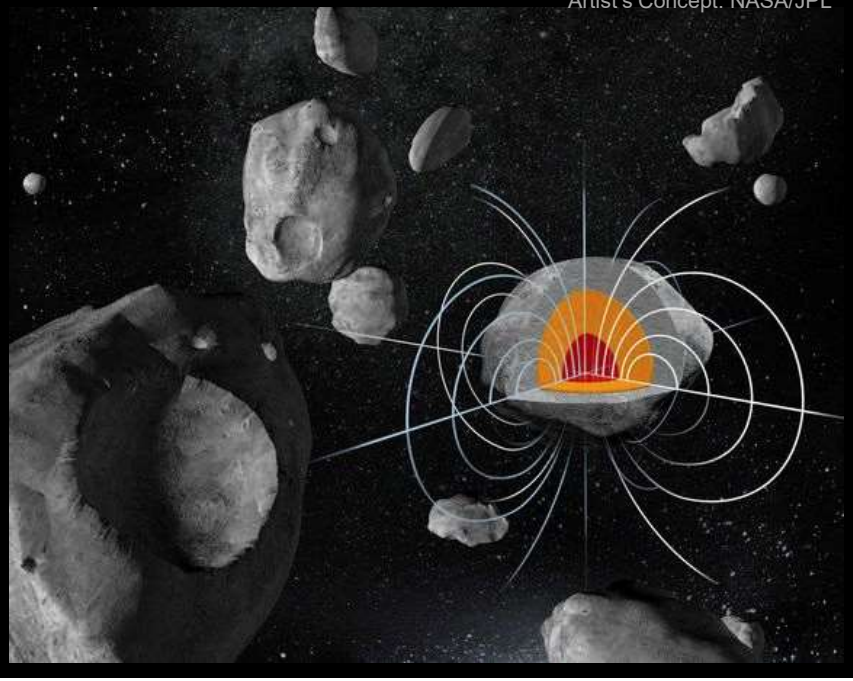
Artists' Concept: NASA/JPL

Concept: Psyche

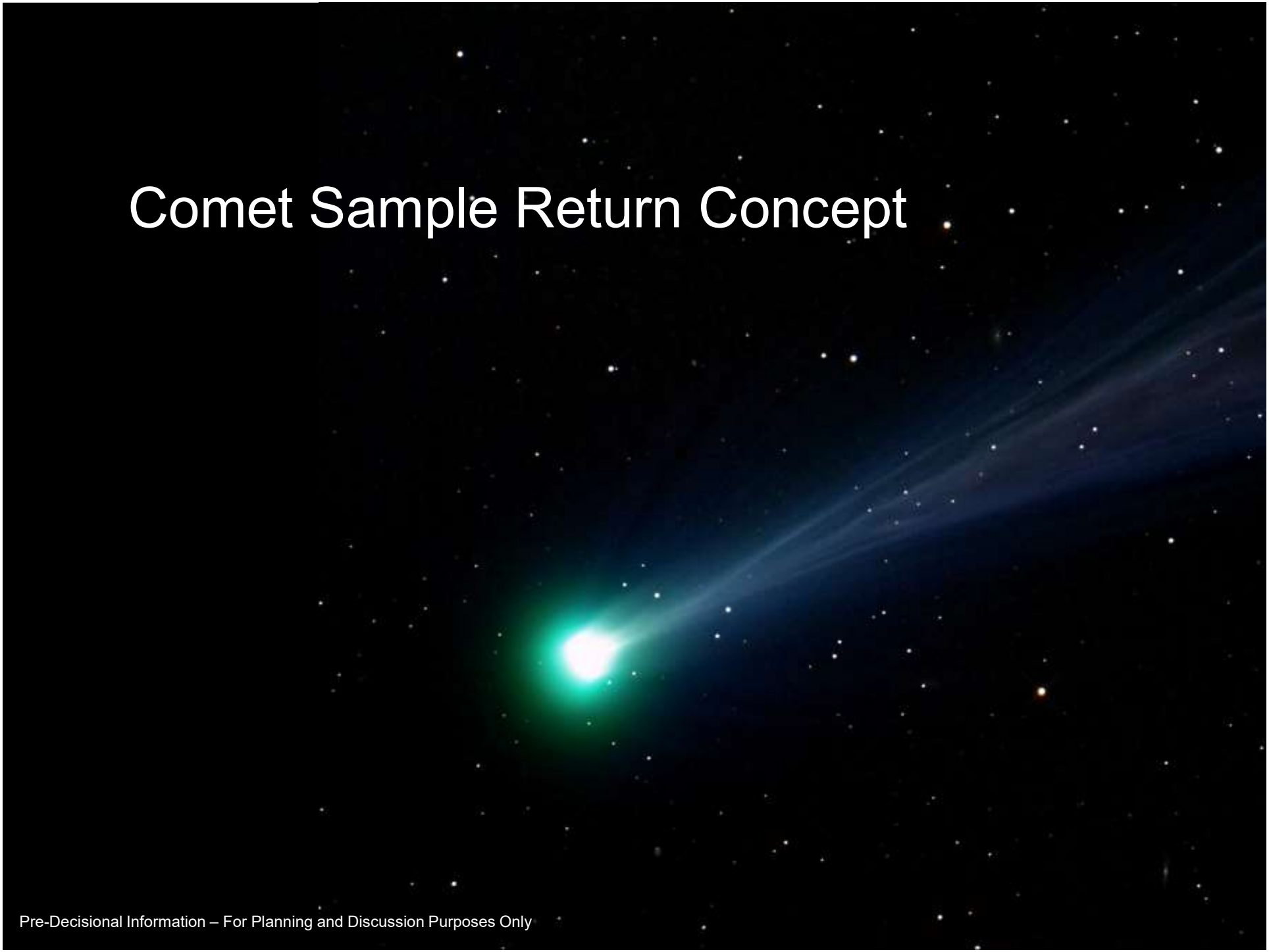
https://www.youtube.com/watch?v=3UkEximY6Ic

JPL Discovery Class Mission
The proposed Psyche mission consists of a robotic spacecraft that would explore the metallic asteroid 16 Psyche to study planet formation.
16 Psyche is a metallic asteroid that may have originated from a protoplanet that had its outer layers stripped during a collison with a planetesimal.
This theory is supported by estimates of Psyche's bulk density, spectra, and radar surface properties; all of which show it to be an unique object in the Asteroid Belt.
The proposed spacecraft would orbit Psyche for six months, studying its topography, surface features, gravity, magnetism, and other characteristics. The mission is largely based on technology that went into the making of NASA's Dawn probe (Ceres).

Artist's Concept: NASA/JPL



Comet Sample Return Concept



Pre-Decisional Information – For Planning and Discussion Purposes Only

Concept: Comet Sample Return

Comet Sample Return

BiBlade is used in a Touch-and-Go (TAG) mission architecture where the spacecraft maneuvers to the surface of a comet, and deploys a sampling tool at the end of a robotic arm to the comet surface.

Blades of the sampling tool are quickly driven into the surface, and the spacecraft thrusts away from the comet immediately upon sampling.

While closed, the blades temporarily encapsulate the sample before sample measurement and final deposit into the sample chamber.

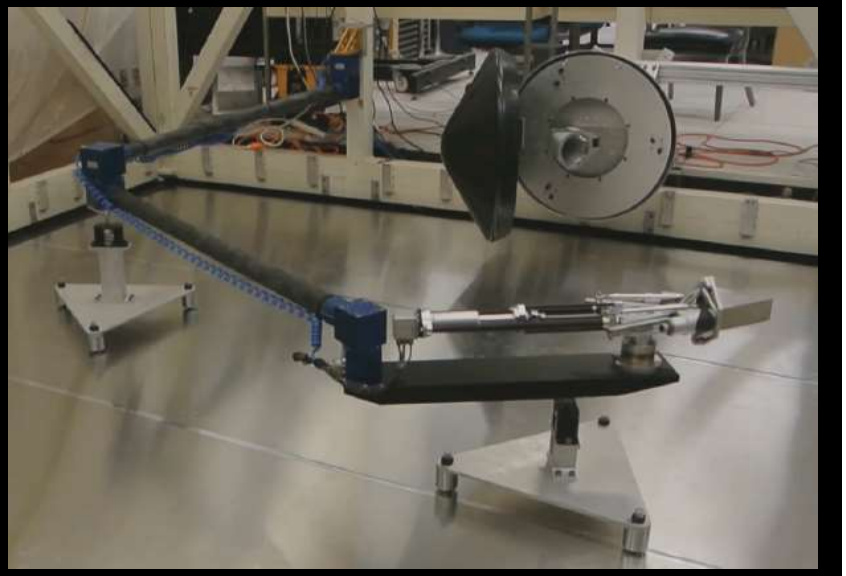
The robotic arm transfers the sampler to a sample measurement station where the sample is measured using a multi-fiberscope sample imager system and the sample is then transferred to a sample chamber in the Sample Return Capsule (SRC).

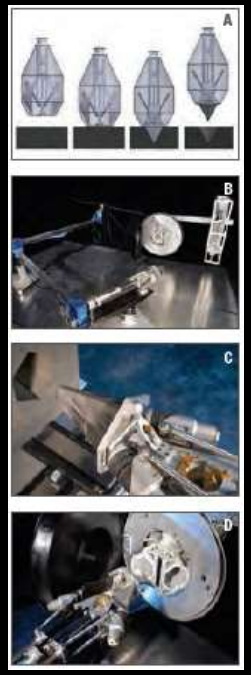
A lid stored on the sampler is released over an SRC sample chamber to encapsulate the sample for return to Earth.

Comet and interstellar dust analyzer (analyzes chemical composition of particles in the comet's coma)

Dust flux monitor (measures size and frequency of dust particles in the coma)

- **Contamination control of sampling tool, measurement station and instrumentation, Sample Return Capsule**
- **Thruster plume induced contamination**
- **Materials outgassing induced contamination**





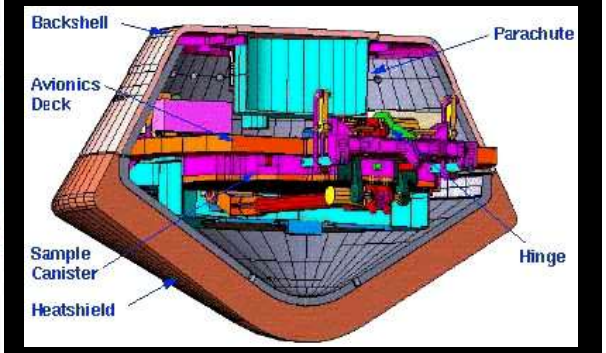


Image Source and Artist's Concept: NASA/JPL

Earth Science Missions and Instruments

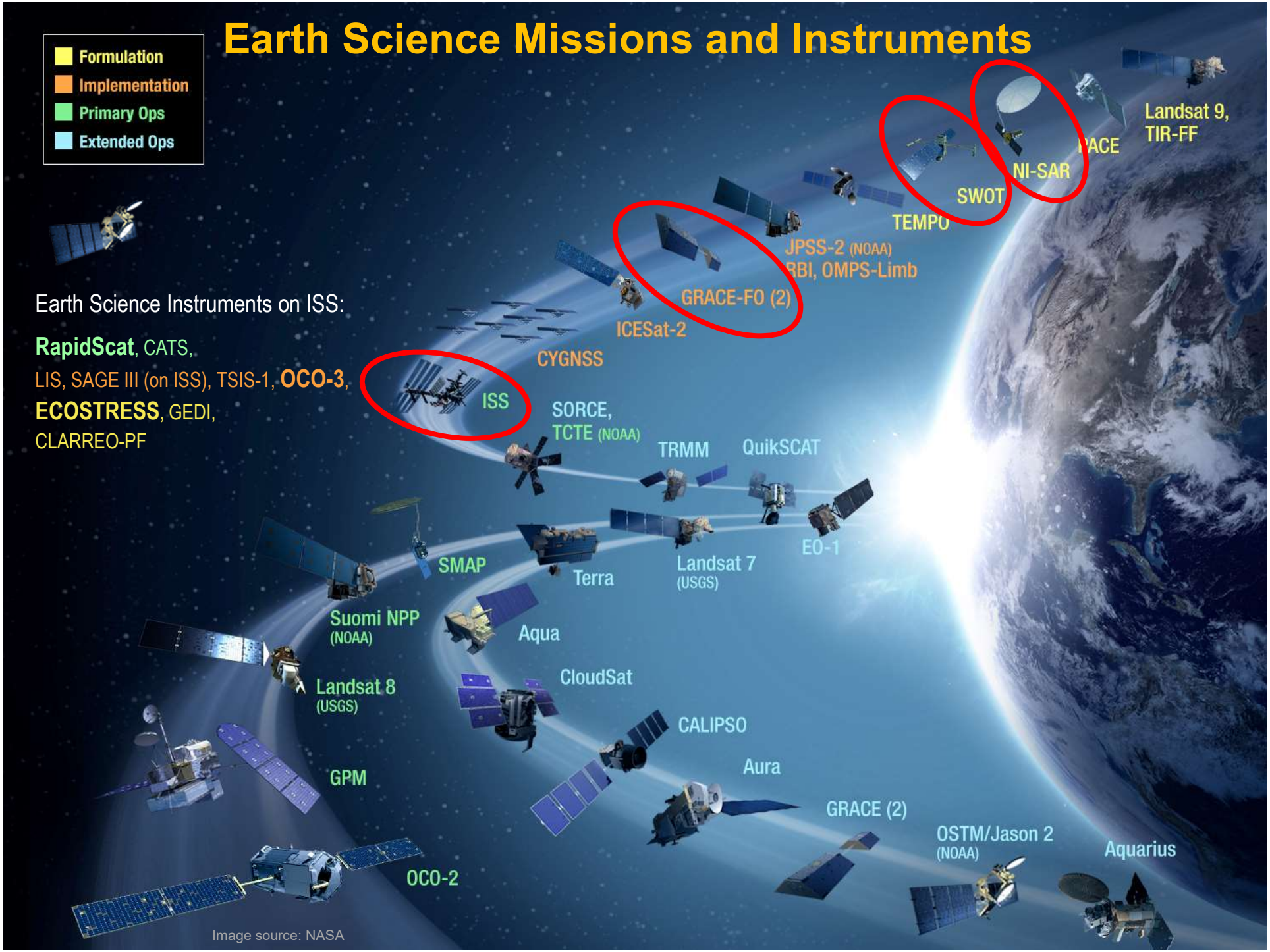


Image source: NASA

ISS Payloads

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) will measure the temperature of plants and use that information to better understand how much water plants need and how they respond to stress.

ECOSTRESS will use a multispectral thermal infrared radiometer to measure the surface temperature.

The Prototype HyspIRI Thermal Infrared Radiometer (PHyTIR) will provide data with 38-m in-track by 69-m cross-track spatial resolution (science requirement is 100 m) and predicted temperature sensitivity of ≤0.1 K (science requirement is 0.3 K).

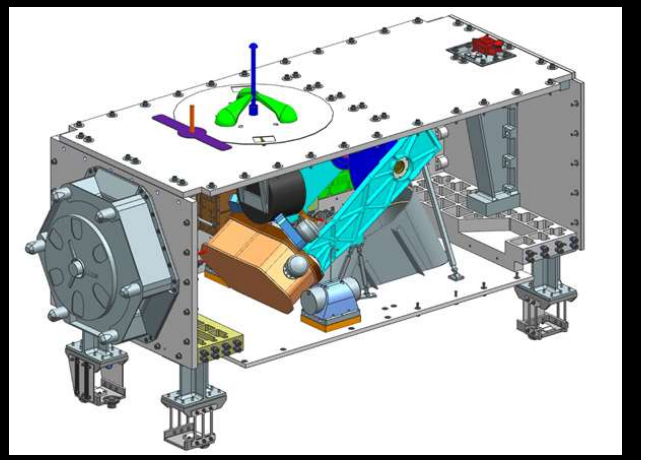
The existing hardware was developed to reduce the cost and risk for the thermal infrared radiometer on the future Hyperspectral Infrared Imager (HyspIRI) mission.

A double-sided scan mirror, rotating at a constant 23.3 rpm, allows the telescope to view a 51°-wide nadir cross-track swath as well as two internal blackbody calibration targets every 1.29 seconds.

The optical signal is focused by a telescope onto the **60 K focal plane** containing a custom 13.2-µm-cutoff mercury-cadmium-telluride (MCT) infrared detector array. Spectral filters on the focal plane define **5 spectral bands in the 8-12.5 µm range and an additional band at 1.6 um** for geolocation and cloud detection (six bands total).

The focal plane is cooled by two **cryocoolers**.

- ***Protection from Dragon trunk induced contamination***



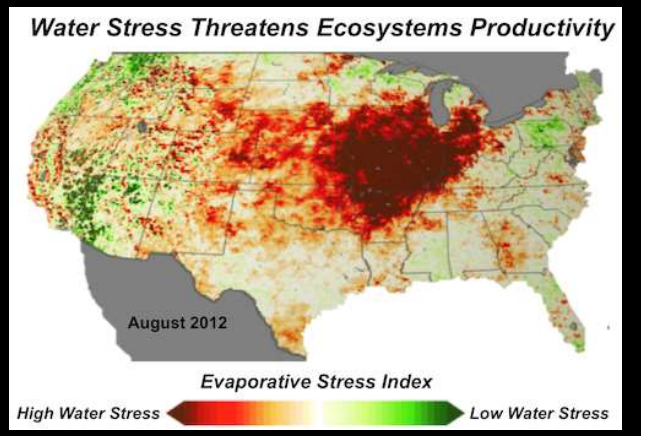


Image source: NASA/JPL

ISS Payloads: OCO-3

Orbiting Carbon Observatory - 3

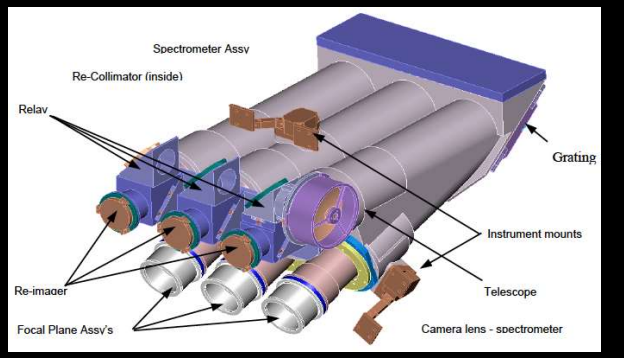
The OCO-3 instrument uses the spare OCO-2 Imaging Spectrometer to characterize the distribution of carbon dioxide on Earth's atmosphere.

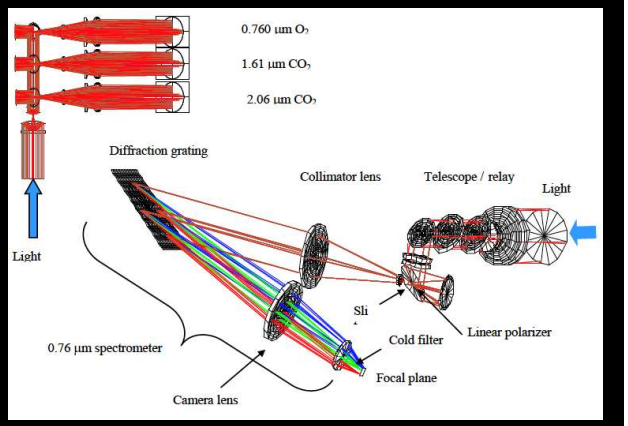
Measurements: atmospheric chemistry, CO_2

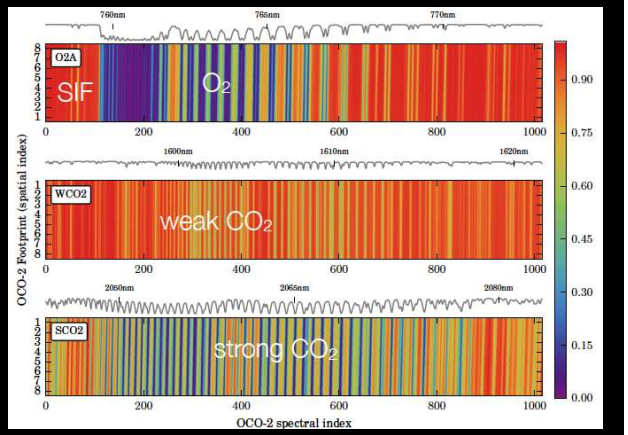
Accuracy: 01. ppm

The instrument consists of ***three high resolution grating spectrometers*** *which collect space-based measurements of atmospheric carbon dioxide (CO_2) with the precision, resolution, and coverage needed to assess the spatial and temporal variability of CO_2 over an annual cycle.*

- ***Thermal vacuum testing***
- ***Protection from Dragon trunk induced contamination***







Resolution	2.25 km downtrack by 0.7 km cross-track
Swath	Soundings ≤ 4.5 km2 in area during Nadir Observation
Accuracy	provide single sounding estimates of XCO2 with one sigma errors of <= 2 ppm
Waveband	0.765 µm, 1.61 µm, 2.06 µm SWIR (~1.3 µm - ~3.0 µm)

Image source: NASA/JPL

NISAR

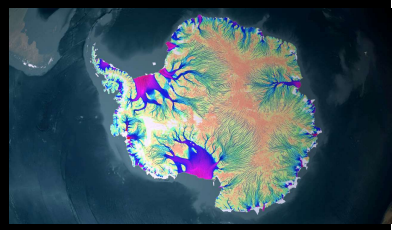
NISAR is a **dual frequency (L+S band) Synthetic Aperture Radar** Mission to be launched in late 2020/ 2021. NISAR is currently in Phase B, having successfully completed PDR in June 2016.

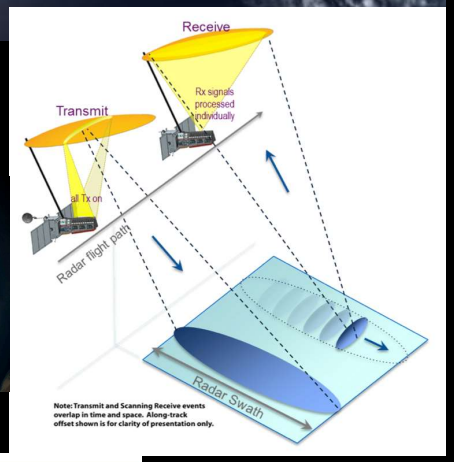
It is a directed mission for implementation by JPL in partnership with Indian Space research Organization (ISRO).

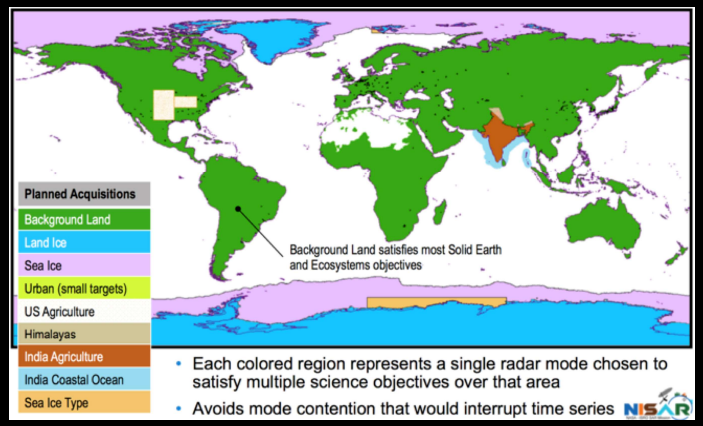
Primary mission operation is planned for 3 years with consumable up to 5 years.

Orbit: 747km altitude circular, 98° inclination, sun-synchronous, dawn-dusk (6 AM – 6 PM); 12-day repeat cycle.

- **Contamination challenges**



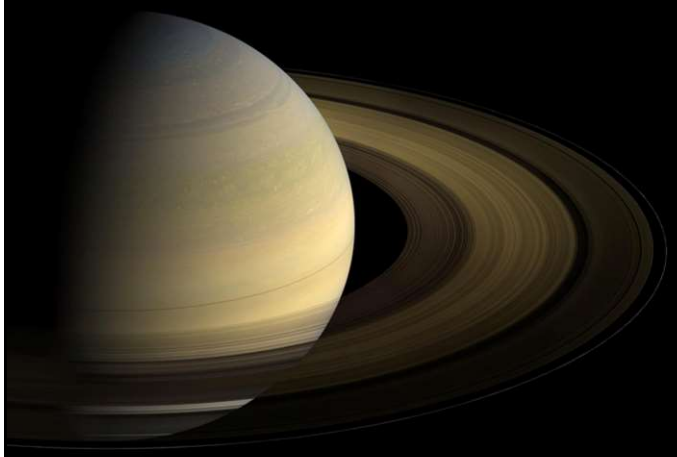




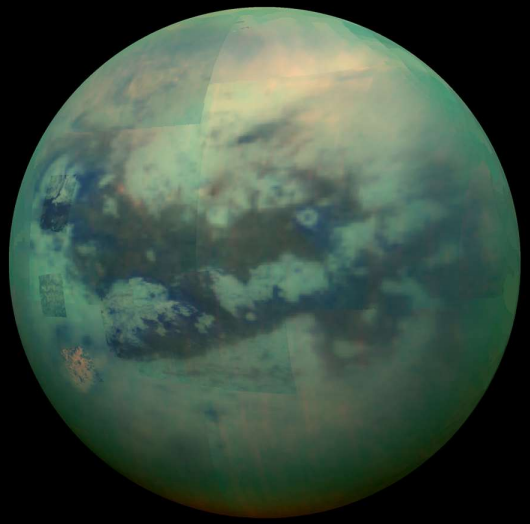
Observation Strategy	L-band		S-band		Culling Approach	
Science Target	Mode*	Resolution	Mode	Resol.	Sampling	Desc Asc
Background Land	DP HH/HV	12 m x 8 m			cull by lat	
Land Ice	SP HH	3 m x 8 m			cull by lat	
Sea Ice Dynamics	SP VV	48 m x 8 m			s = 1 p	
Urban Areas		6 m x 8 m			s = 1 p	
US Agriculture	QP HH/HV VV/VH				s = 1 p	
Himalayas			CP RH/RV		s = 1 p	
India Agriculture					s = 1 p	
India Coastal Ocean			DP HH/HV or VV/VH		s = 1 p	
Sea Ice Types	DP VV/VH				s = 3 p	

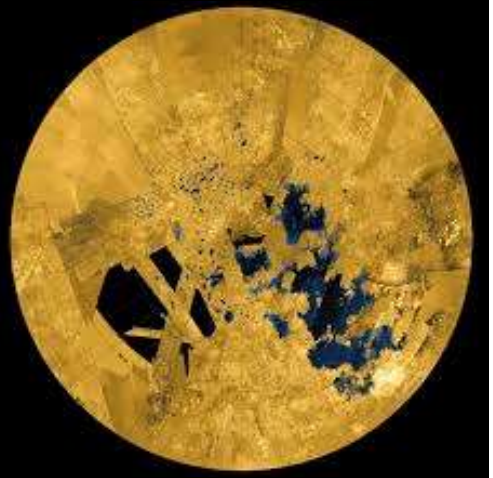
Image source: NASA/JPL

Other Mission Concepts

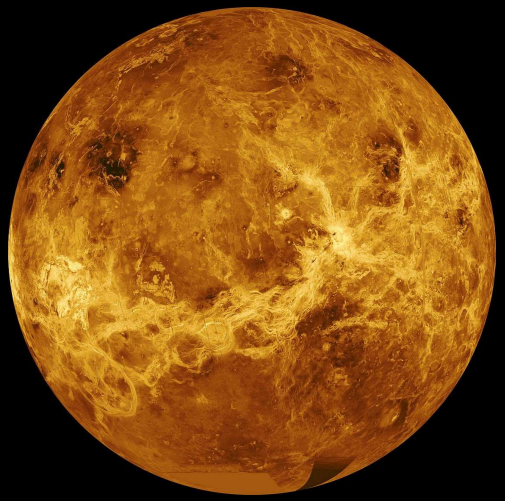


Titan
[Orbiter & Probe]





VERITAS
(Venus)



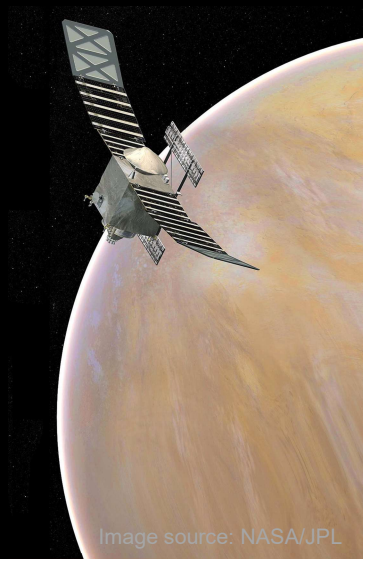


Image source: NASA/JPL

Concept: NEOCam –Asteroid Finder

The Near-Earth Object Camera (NEOCam) is a new mission proposal designed to discover and characterize most of the potentially hazardous asteroids that are near the Earth.

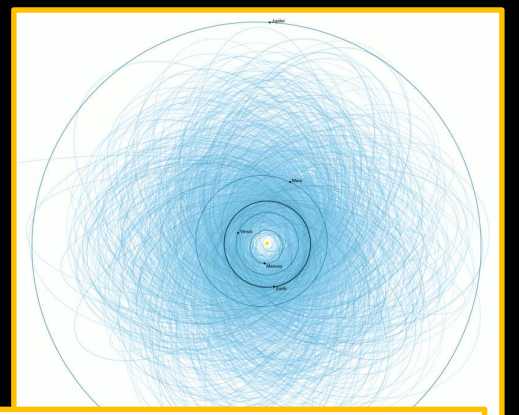
Instrument: 50 cm diameter telescope operating at two heat-sensing infrared wavelengths; capable of detecting even the dark asteroids that are hardest to find.

Mission: four year baseline survey to find 2/3 of the near-Earth objects larger than 140 m (large enough to cause major regional damage in the event of an Earth impact).

Accurate measurements of NEO sizes and can gain valuable information about their composition, shapes, rotational states, and orbits.

NEOCam employs an innovative observation strategy to independently discover new asteroids and comets and determine their orbits with enough accuracy to allow them to be found again.

- **Identified key contamination risks**
- **Developed mitigation options.**
- **Assessed risk of ice contamination on sensitive surfaces.**



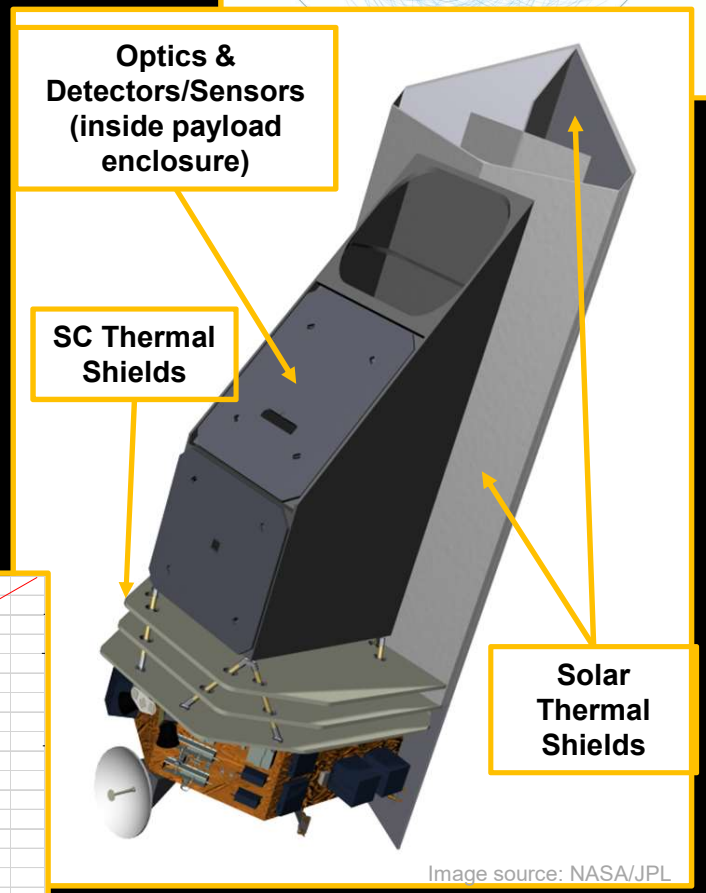
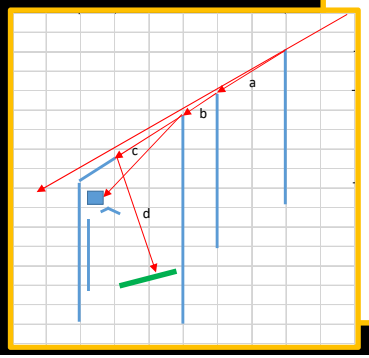


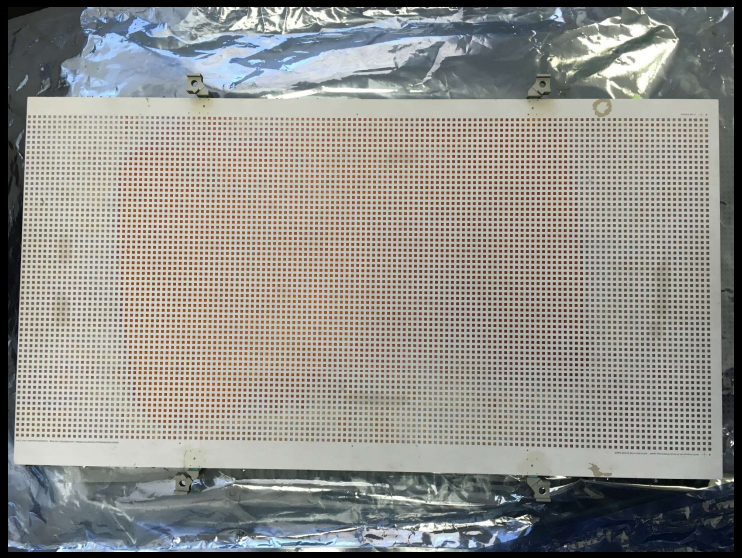
Image source: NASA/JPL



JPL Materials & Processes

- Structural materials engineering and testing is in one group (353C)
- The group has three primary functions
  - Flight materials engineering support, covering polymerics, metals, ceramics, and composites
  - Service center (laboratories) responsible for heat treatment, mechanical testing, composite fabrication, thermal vacuum and environmental testing, outgassing testing (ASTM E595) and adhesive bonding
  - Research and development in focused areas relating to core charter
- Materials & Processes (M&P) is co-located in Section 353 with Analytical Chemistry and Contamination Control (CC)
  - For ~ 10 years, M&P and CC functioned as one group

Mechanical testing of the Mars Science Laboratory (Curiosity) rover wheel

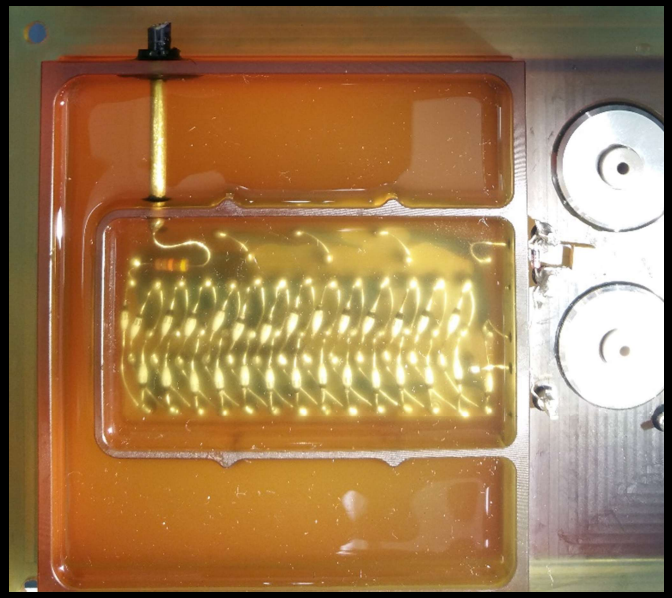


SWOT KaRIN Reflectarray breadboard composite panel fabricated at JPL

Courtesy of Bryan McEnerney, JPL Materials Engineering, Test and Evaluation

Typical Project Workflow

- JPL often has M&P and CC on the same WBS structure, emphasizing the interrelationship between the groups
- Flight Engineering Support
  - M&P chooses materials and develops the MIUL in conjunction with the CC engineering staff
  - Target issues are worked at the grass-roots level early in the design phase and undesirable materials are identified
  - Conversely, new materials can be identified and tested to solve challenging issues (e.g. ultra-low outgassing silicones and new paint qualification for Mars 2020)
  - M&P Control Plans reviewed by CC prior to release for PDR/CDR
- Outgassing testing, environmental and thermal vacuum bakeouts are conducted by M&P at the behest of CC and in full conjunction with analytical chemistry
  - Approach is complementary between all groups



Planetary Instrument for X-ray Lithochemistry (PIXL) HVPS De-bond

High-voltage power supply had a de-bond of the potting compound, which led to destructive arcing.

1. Materials & Processes tested the as-cured material to ensure that the non-standard cure met ASTM E595 requirements set by project contamination control guidelines.
2. Analytical Chemistry performed surface analysis for contamination control to see if processing was suspect.
3. Contamination Control Engineering involved in all aspects and investigated secondary challenges.

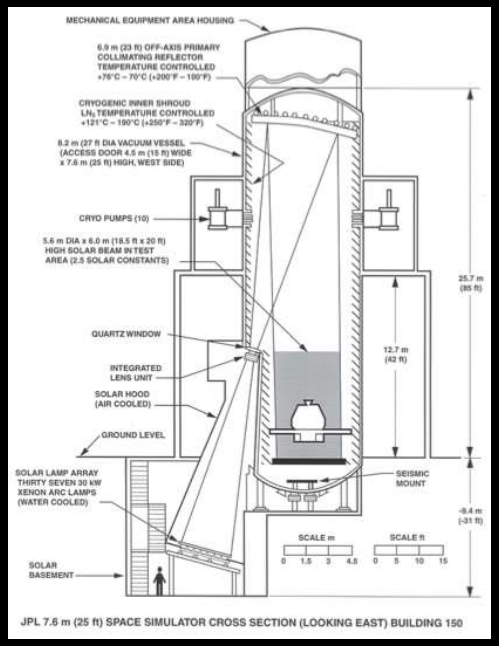
Courtesy of Bryan McEnerney, JPL Materials Engineering, Test and Evaluation

Environmental Test Laboratory (ETL) Space/Solar Simulator Facilities

The Environmental Test Laboratory (ETL) provides all JPL projects (and external customers) with complete facilities for thermal, thermal-vacuum, solar-thermal-vacuum, vibration, mechanical shock and acoustic testing for all types of space flight hardware.

Contamination Control:

- **Thermal vacuum baking and testing (qualification, proto-flight, flight acceptance, planetary protection)**
- **CQCM/TQCM monitoring and verification of exit criteria**
- **NVR and particle testing/monitoring**



JPL 7.6 m (25 ft) SPACE SIMULATOR CROSS SECTION (LOOKING EAST) BUILDING 150

Image source: NASA/JPL

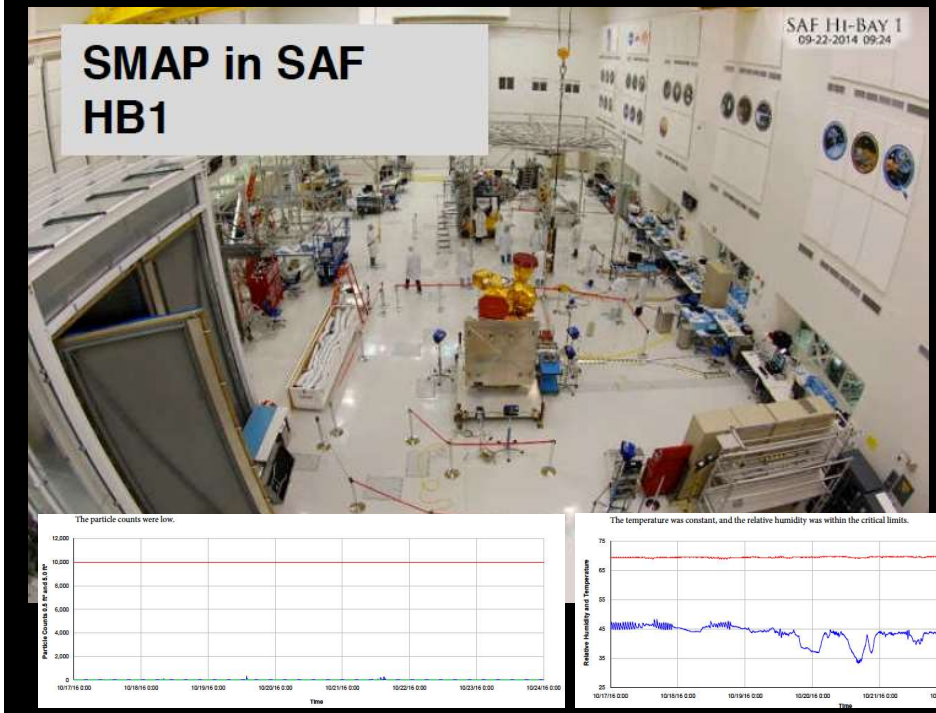
Mission Integration & Testing
Spacecraft Assembly Facility

The Spacecraft Assembly Facility (SAF) houses high bays one and two:

- High bay one (HB1) is nearly 14 meters (approximately 45 feet) tall
- High bay two (HB2) has a width, length and height of approximately 21 meters (about 70 feet)

Contamination Control:

- **Cleanroom environmental monitoring/control**
- **NVR and particle testing/monitoring**



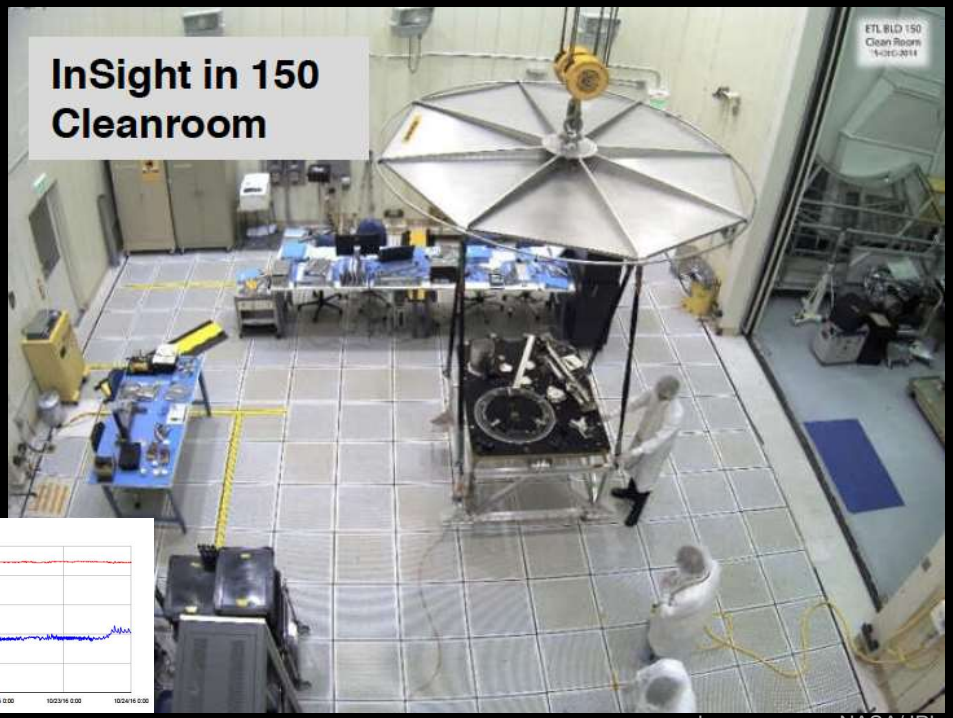
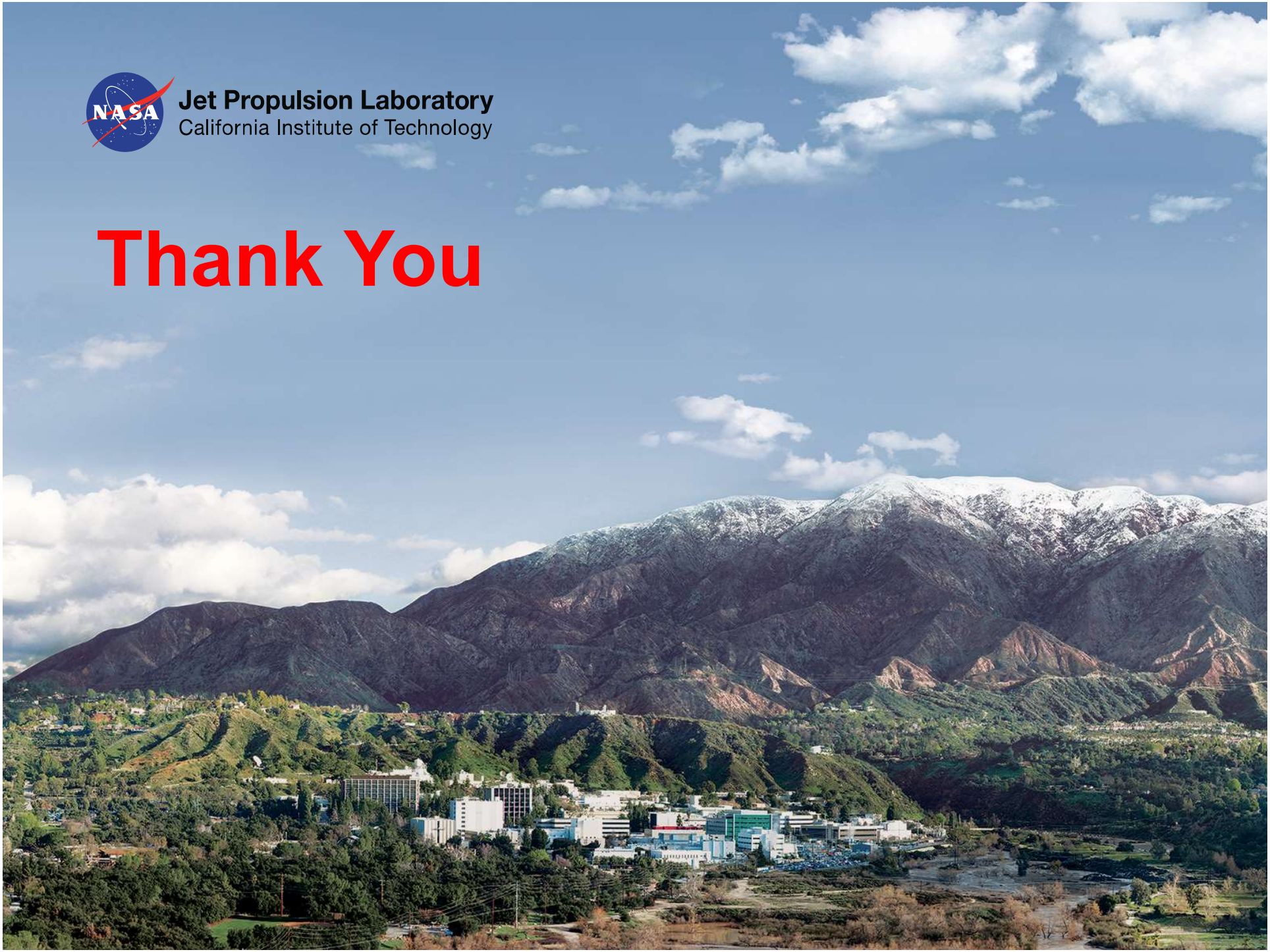


Image source: NASA/JPL

Jet Propulsion Laboratory
California Institute of Technology

Thank You