The Sample Analysis at Mars (SAM) Developing Analytical Tools to Search for a Habitable Environment on Mars

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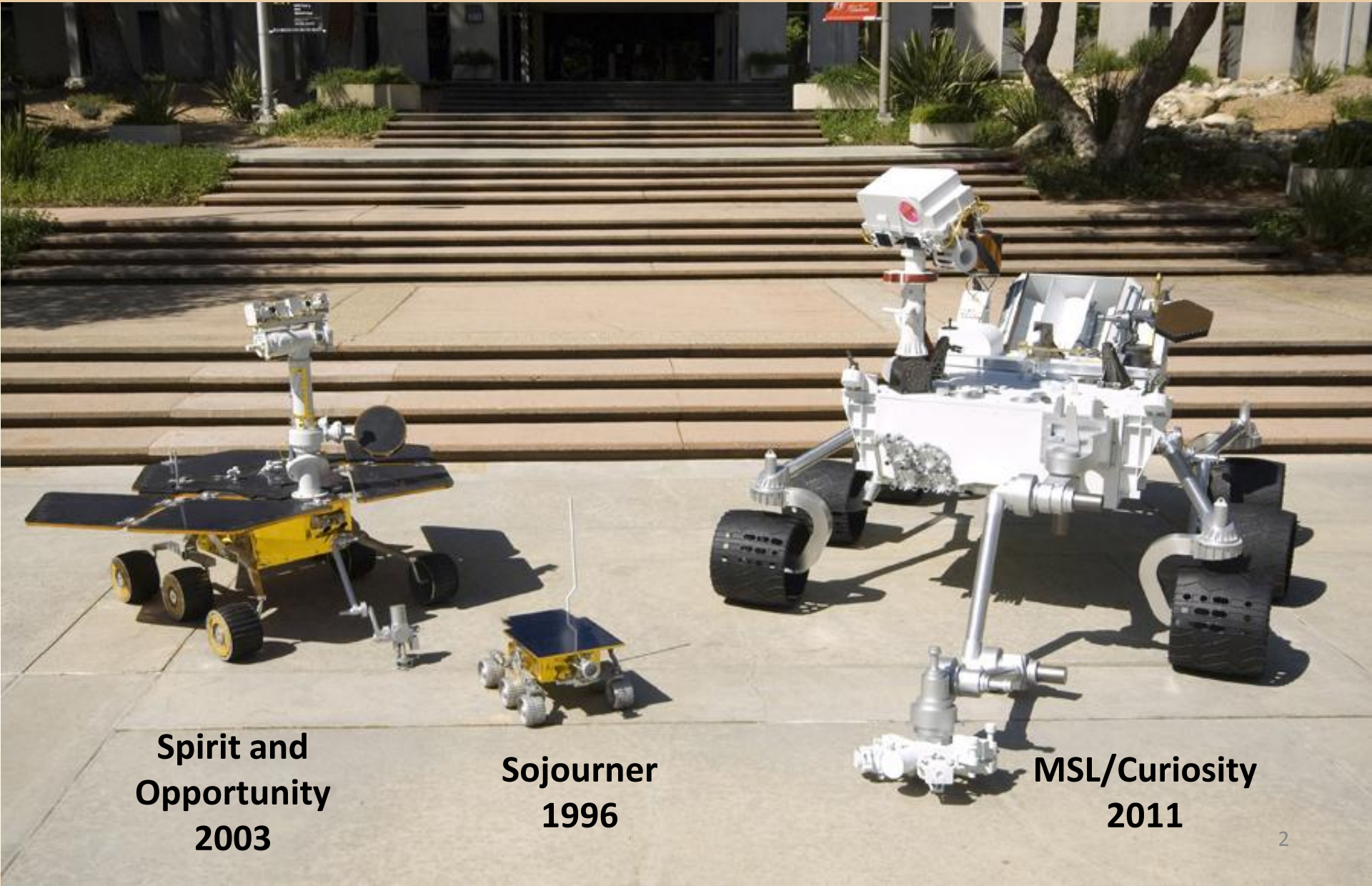
Rover Family Portrait



Curiosity's Capabilities

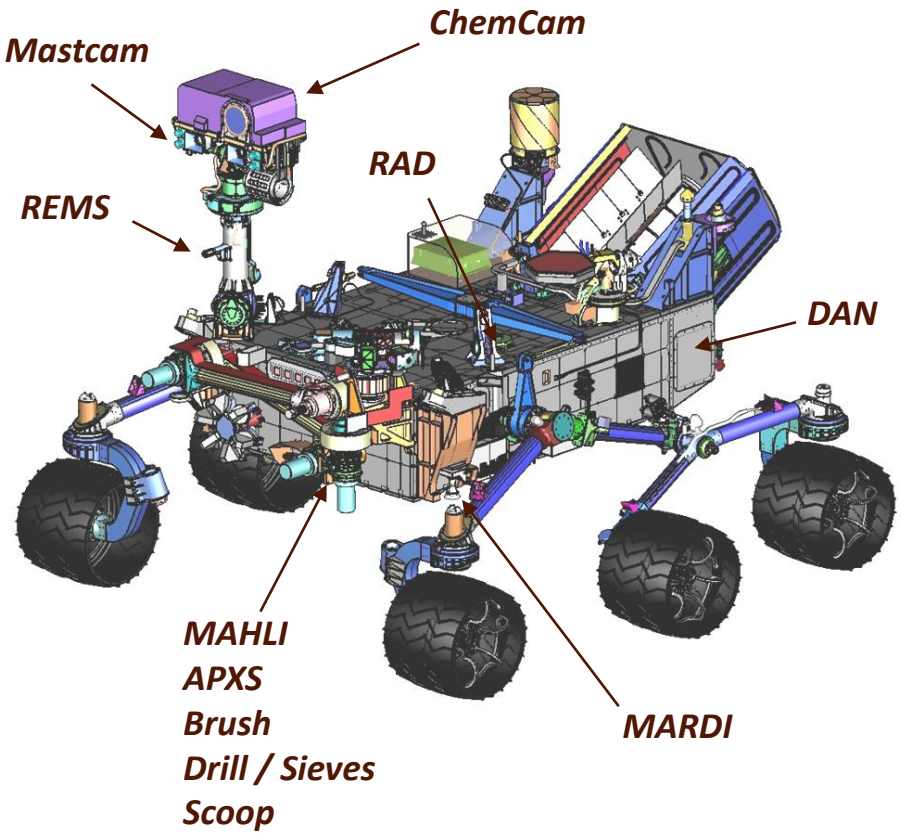
A Robotic Field Geologist

- Long life, ability to traverse many miles over rocky terrain
- Landscape and hand-lens imaging
- Ability to survey composition of bedrock and regolith

A Mobile Geochemical and Environmental Laboratory

- Ability to acquire and process dozens of rock and soil samples
- Instruments that analyze samples for chemistry, mineralogy, and organics
- Sensors to monitor water, weather, and natural high-energy radiation

MSL Science Payload



Rover Width:	**2.8 m**
Height of Deck:	**1.1 m**
Ground Clearance:	**0.66 m**
Height of Mast:	**2.2 m**

REMOTE SENSING

Mastcam (M. Malin, MSSS) - Color and telephoto imaging, video, atmospheric opacity

ChemCam (R. Wiens, LANL/CNES) – Chemical composition; remote micro-imaging

CONTACT INSTRUMENTS (ARM)

MAHLI (K. Edgett, MSSS) – Hand-lens color imaging

APXS (R. Gellert, U. Guelph, Canada) - Chemical composition

ANALYTICAL LABORATORY (ROVER BODY)

SAM (P. Mahaffy, GSFC/CNES) - Chemical and isotopic composition, including organics

CheMin (D. Blake, ARC) - Mineralogy

ENVIRONMENTAL CHARACTERIZATION

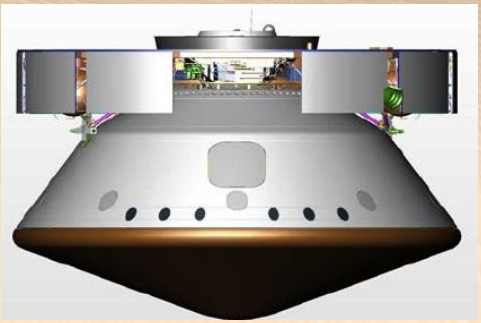
MARDI (M. Malin, MSSS) - Descent imaging

REMS (J. Gómez-Elvira, CAB, Spain) - Meteorology / UV

RAD (D. Hassler, SwRI) - High-energy radiation

DAN (I. Mitrofanov, IKI, Russia) - Subsurface hydrogen

Mission Overview



CRUISE/APPROACH

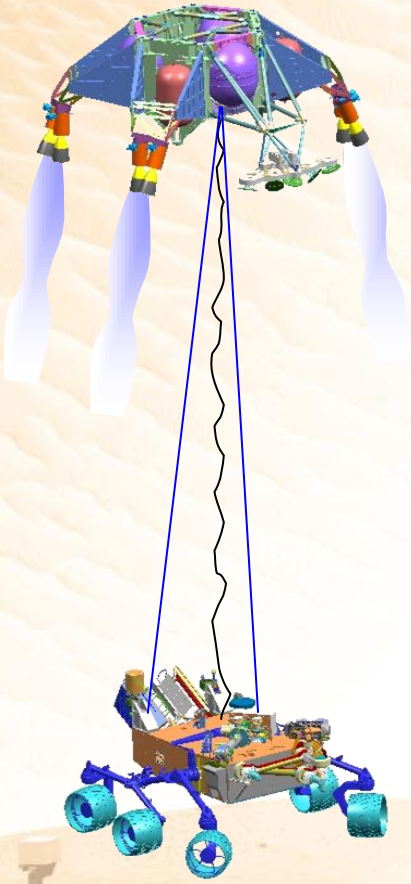
- 8 to 9-month cruise
- Arrive August 6-20, 2012

LAUNCH

- Window is Nov. 25 to Dec. 18, 2011
- Atlas V (541)

ENTRY, DESCENT, LANDING

- Guided entry and powered "sky crane" descent
- 20×25-km landing ellipse
- 900-kg rover



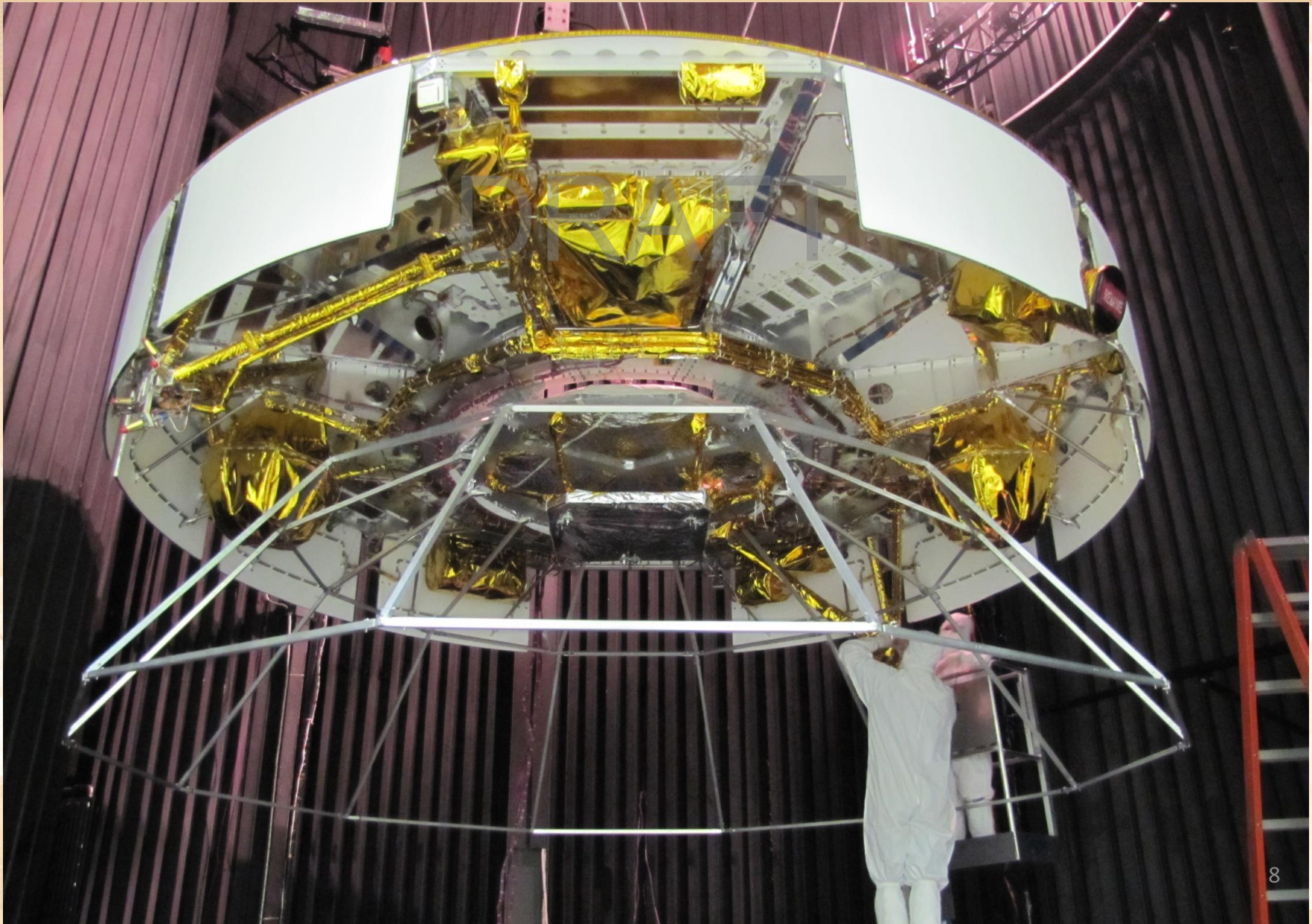
SURFACE MISSION

- Prime mission is one Mars year (687 days)
- Ability to drive out of landing ellipse
- 84 kg of science payload
- Direct (uplink) and relayed (downlink) communication

Curiosity under going testing in JPL's Gravel Pit

Curiosity's Rock Grinder and Drill

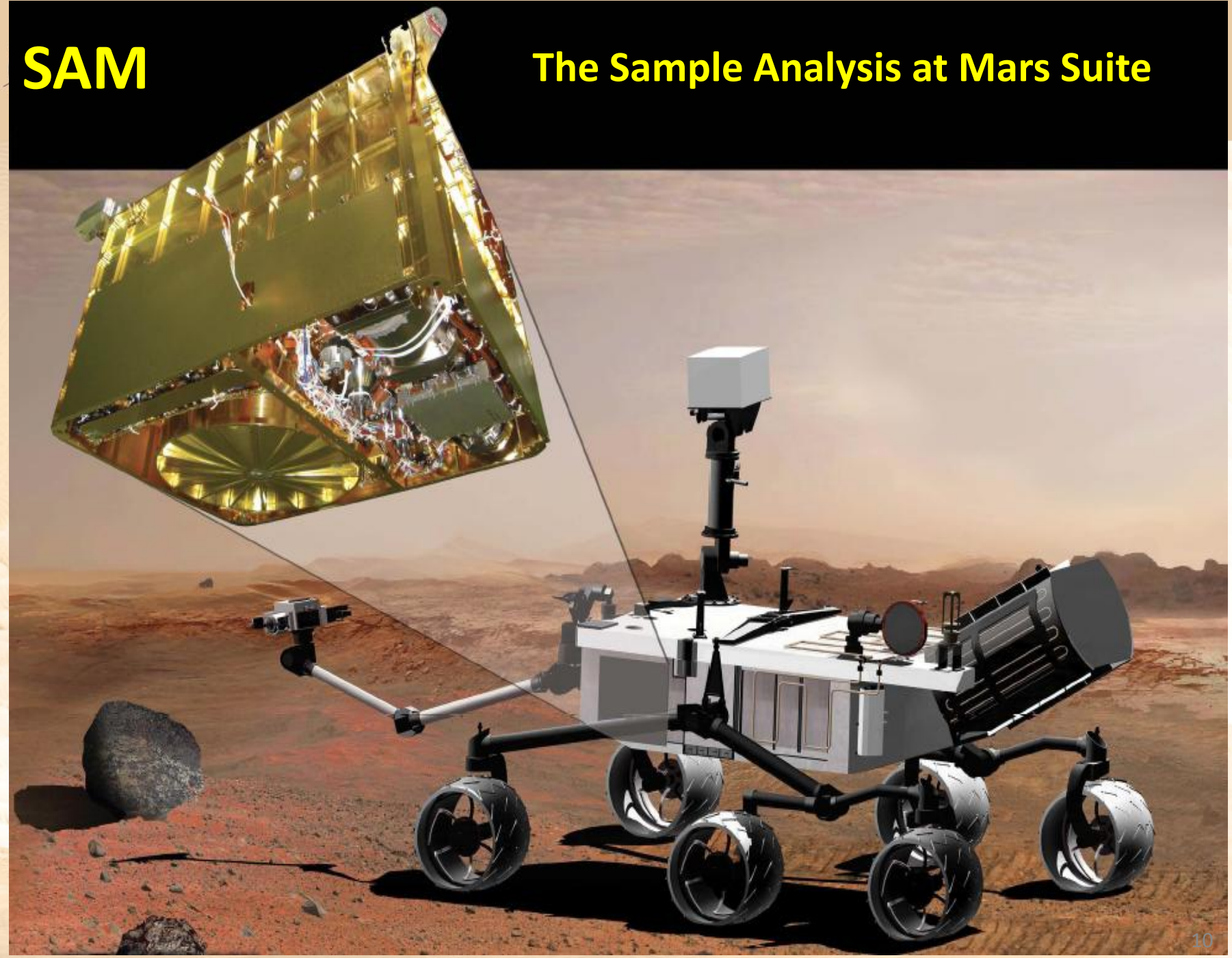
Cruise Stage



Assembled Spacecraft

SAM

The Sample Analysis at Mars Suite



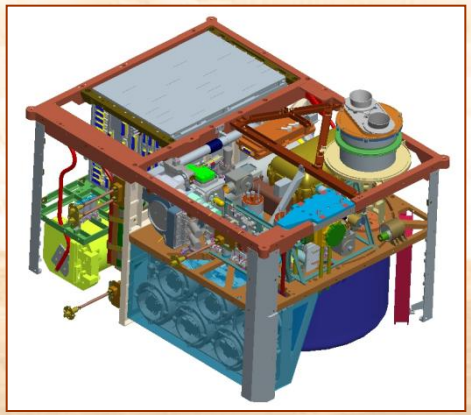
SAM – The Sample Analysis at Mars Suite

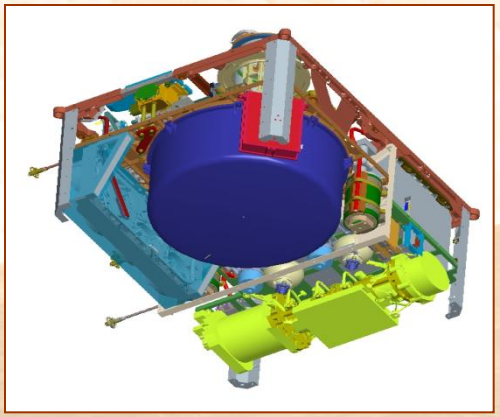
SAM is a Suite of 3 Instruments

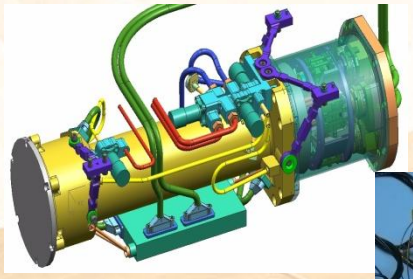
- **Quadrupole Mass Spectrometer (QMS) – Goddard Space Flight Center**
  - Molecular and isotopic composition in the 2-535 Dalton mass range for atmospheric and evolved gas samples
- **Gas Chromatograph (GC) - University of Paris, CNES**
  - Resolves complex mixtures of organics into separate components
- **Tunable Laser Spectrometer (TLS) – Jet Propulsion Laboratory**
  - Abundance and precision isotopic composition of CH_4, H_2O, and CO_2

SAM supporting subsystems

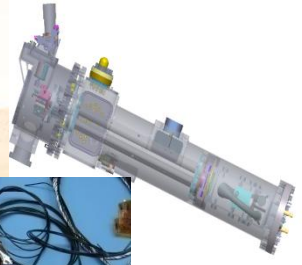
- **Gas Processing System (GPS) – Goddard Space Flight Center**
  - Includes valves, manifolds, carrier gas, enrichment cells, Wide Range Pump (WRP), and Pyrolysis Ovens
- **Sample Manipulation System (SMS) – Honeybee Robotics**
  - Positions 74 sample cups to below a sample inlet tube or into SAM pyrolysis ovens
  - 59 quartz cups, 9 derivatization cups, 6 cal cups
- **Common Infrastructure Systems – Goddard Space Flight Center – engineering, software etc**



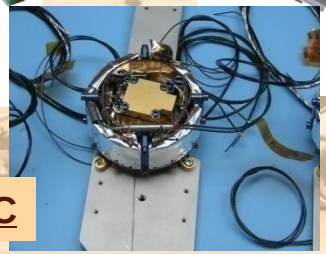




TLS



QMS



GC

SAM – Core science goals

- **GOAL #1: Explore sources and destruction paths for carbon compounds**

  Met by measurements of the identity and abundance of **organic molecules** and their distribution of oxidation states, molecular weights, and chemical structures

- **GOAL #2: Search for organic compounds of biotic and prebiotic relevance including methane**

  Met by measurements of:
  - **amino acids, nucleobases, carboxylic acids** by solvent extraction and chemical derivatization
  - **methane abundance** in the atmosphere & its **$^{13}C/^{12}C$ ratio** with TLS.

- **GOAL #3: Reveal chemical and isotopic state of other light elements that are important for life as we know it on Earth**

  Met by measurement of **inorganic gases** such as SO_2, H_2O, and CO_2 evolved from solid samples

- **GOAL #4: Study habitability of Mars by atmospheric/surface interactions expressed in trace species compositions**

  Met by measurement of
  - abundance of multiple minor and **trace atmospheric species** including those with short photochemical atmospheric lifetimes
  - **diurnal and seasonal variation of atmospheric species** such as H_2O, O_2, N_2, Ar, O_3, H_2, and CH_4

- **GOAL #5: Understand atmosphere & climate evolution through isotope measurements of noble gases & light elements**

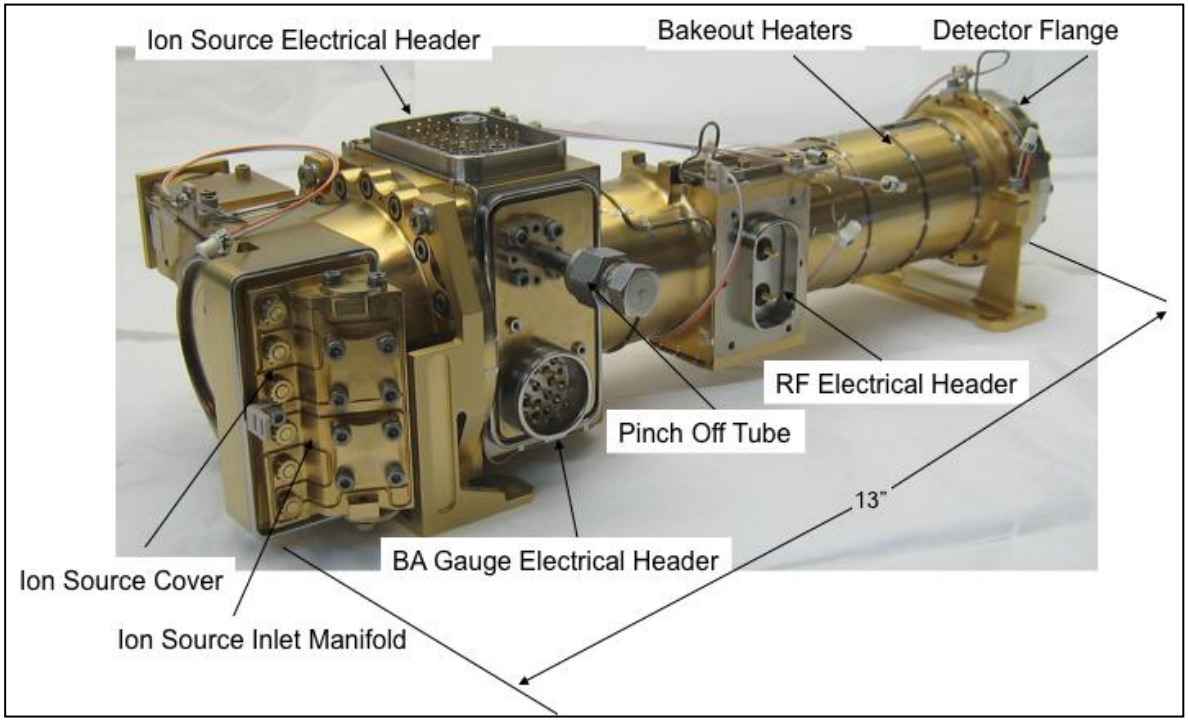
  Met by measurement in the atmosphere and in gas evolved from fines and powdered rocks
  - **isotope ratios for noble gases**
  - **$^{13}C/^{12}C$, $^{15}N/^{14}N$, $^{18}O/^{16}O$, $^{17}O/^{16}O$, and D/H** in simple compounds

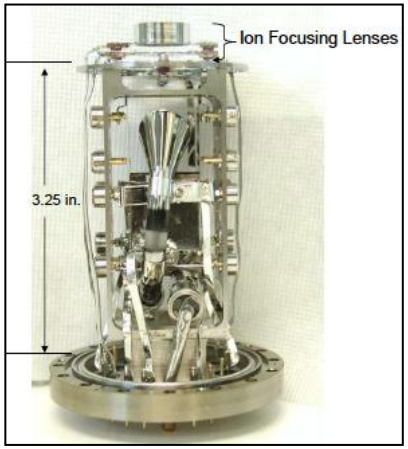
  provides a database that constrains models of atmospheric evolution and identifies reservoirs of the light elements that contribute to the present atmosphere.

SAM Quadrupole Mass Spectrometer (QMS)

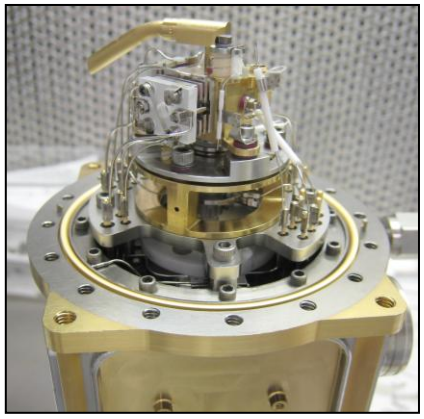
QMS features

- precision assembly hyperbolic rods
- titanium alloy housing
- in situ bakeout
- 3 frequency RF
- pressurized enclosure for RF electronics
- 2-535 Da
- dual electron guns
- dual detectors
- 2 direct atmosphere inlets
- 6 gas chromatograph inlets

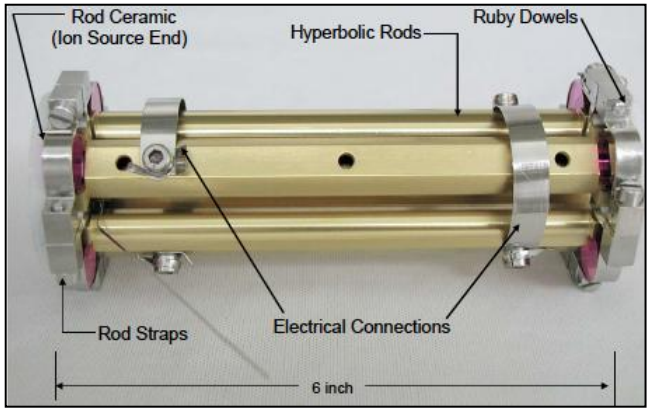




Dual 4870 Channeltron Multipliers

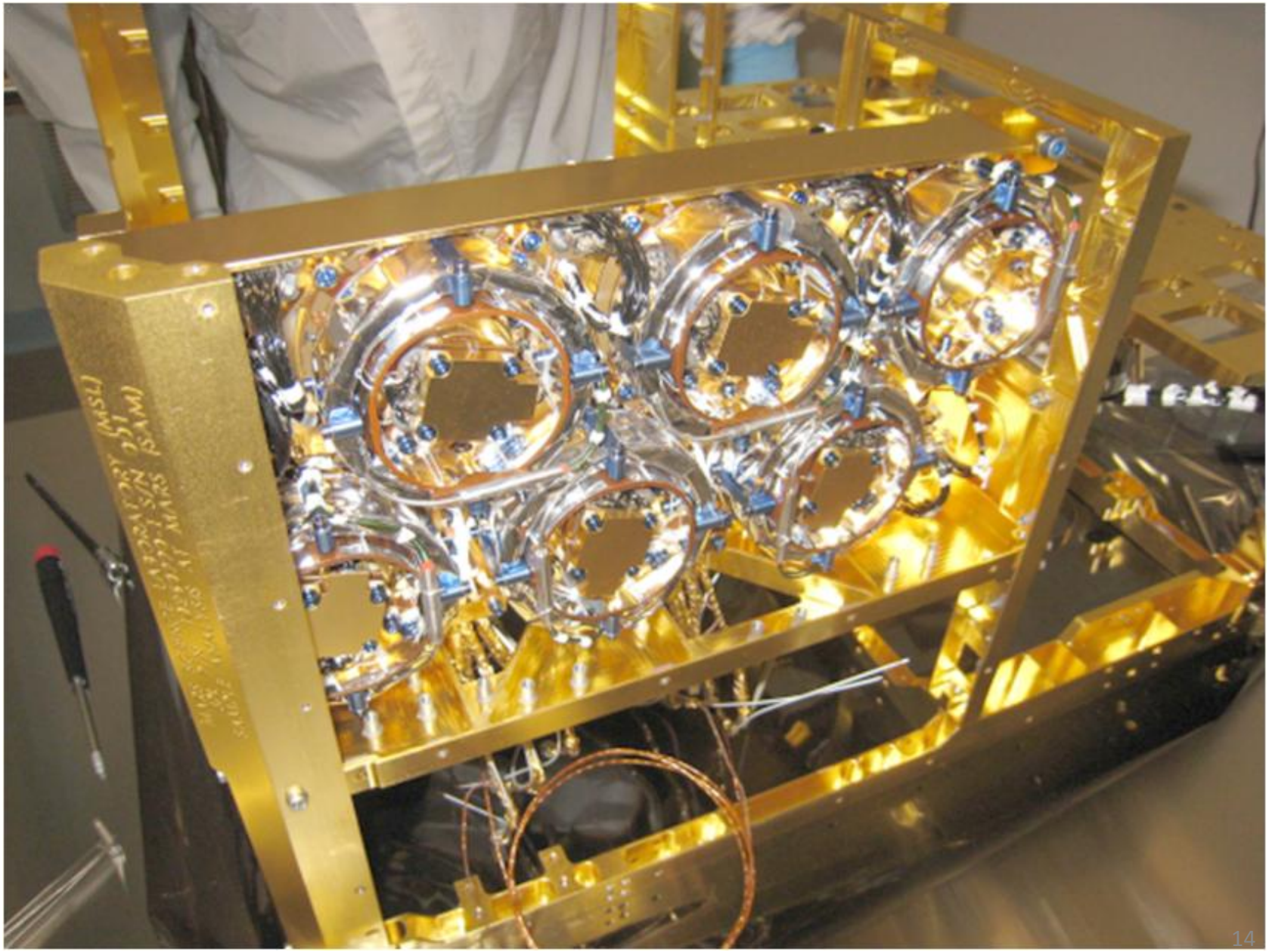


Ion Source (Dual Electron Guns)



6" Long Hyperbolic Rod Analyzer

SAM Gas Chromatograph (GC)

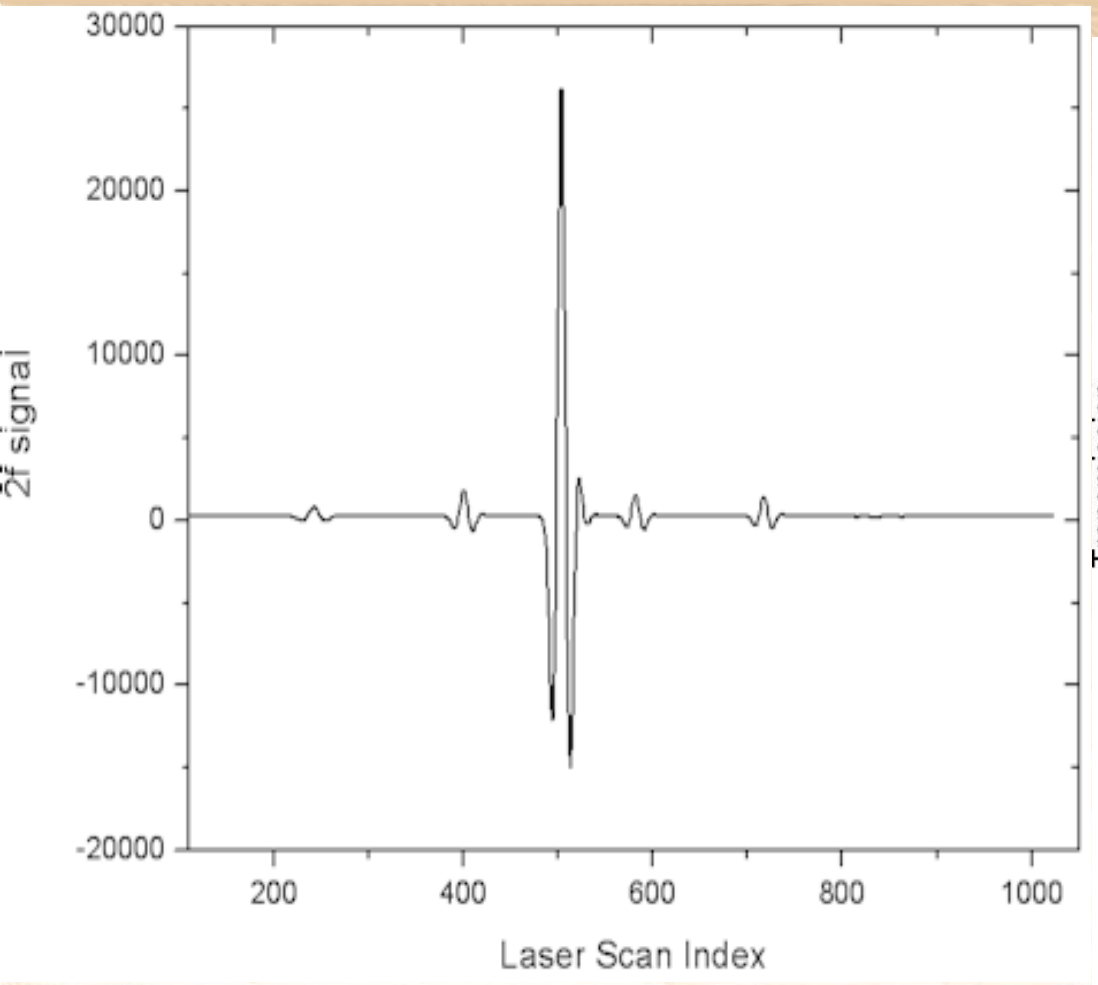


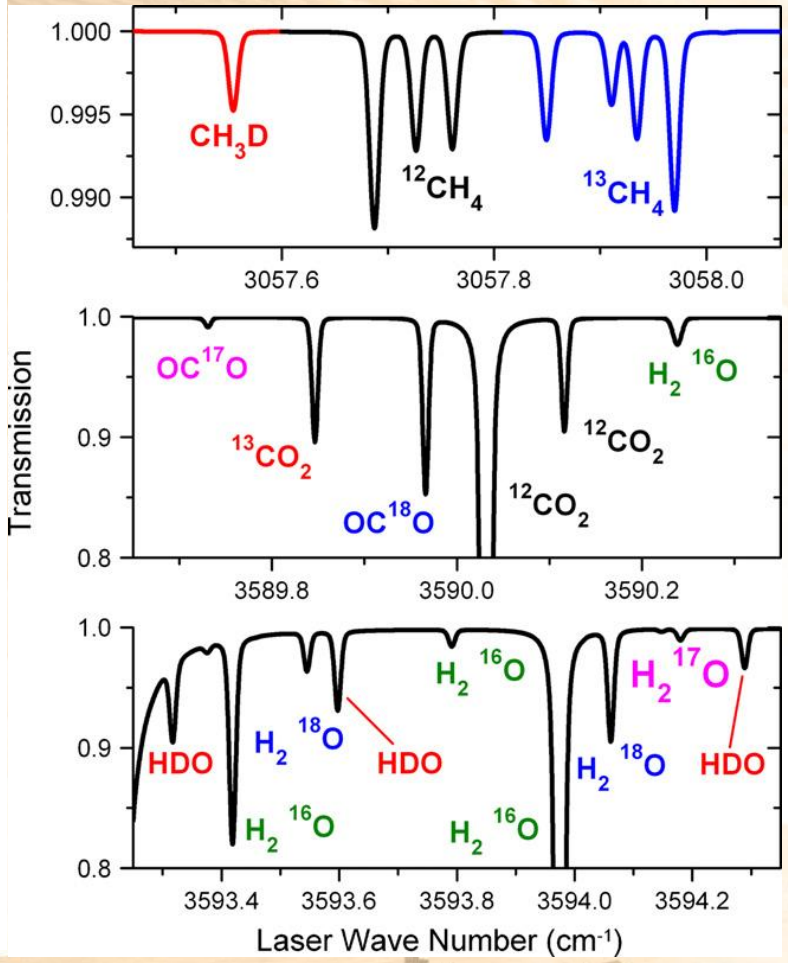
SAM GC Columns

EM columns	Stationary phase	Species targeted	Stationary phase	FM columns
Carbobond (PLOT)	Carbon molecular sieve	Permanent gases C_1-C_2 HCs	Carbon molecular sieve	Carbobond (PLOT)
MXT U (PLOT)	Divinylbensene	C_1-C_4 organics NH3, S containing compounds	Divinylbenzene or substituted divinylbenzene	MXT U or Q (PLOT)
MXT 20 (WCOT)	polydimethylsiloxane with 20% of phenyl	Medium molecular weight organics (C_5-C_{15} organics)	polydimethylsiloxane with 20% of phenyl	MXT 20 (WCOT)
MXT CLP (WCOT)	polydimethylsiloxane with phenyl and cyanopropyle	Medium molecular weight organics (C_5-C_{15} organics)	polydimethylsiloxane with phenyl and cyanopropyle	MXT CLP (WCOT)
MXT 5 (WCOT)	polydimethylsiloxane with 5% of phenyl	High molecular weight VOCs including derivatives (>C_{15} organics)	polydimethylsiloxane with 5% of phenyl	MXT 5 (WCOT)
Chirasil-β Dex CB	β cyclodextrin	Enantiomers of VOCs	β cyclodextrin	Chirasil-β Dex CB

All the columns have the same dimensions (L=30 m, ID=0.25 mm and d_f=0.25 for the WCOT and 10 µm for the PLOTs)

TLS samples 3 spectral regions

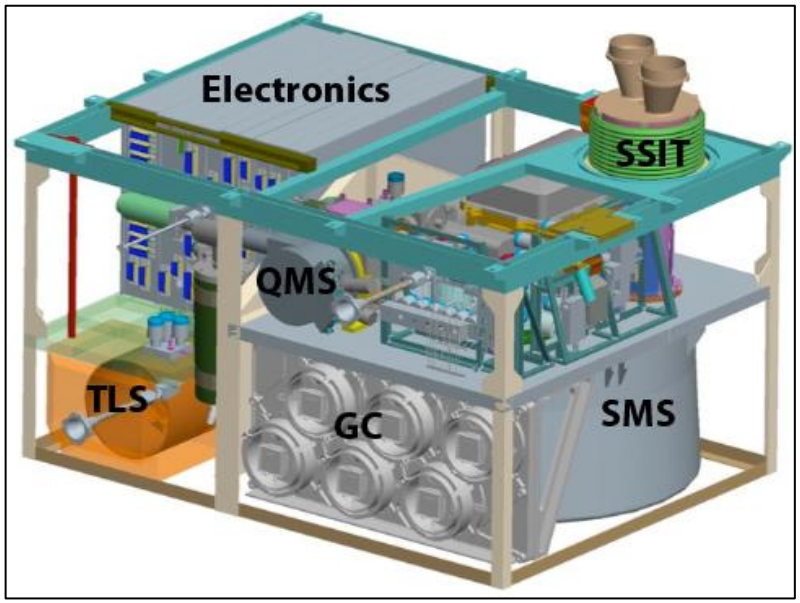


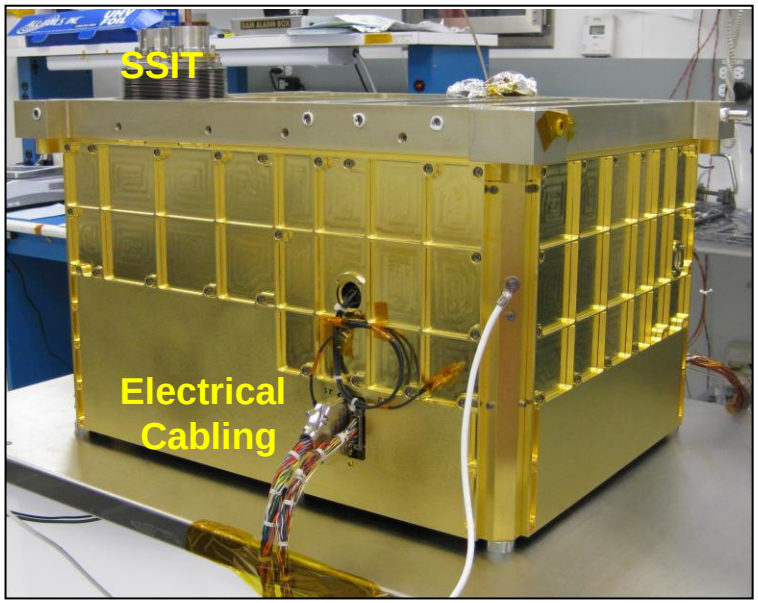


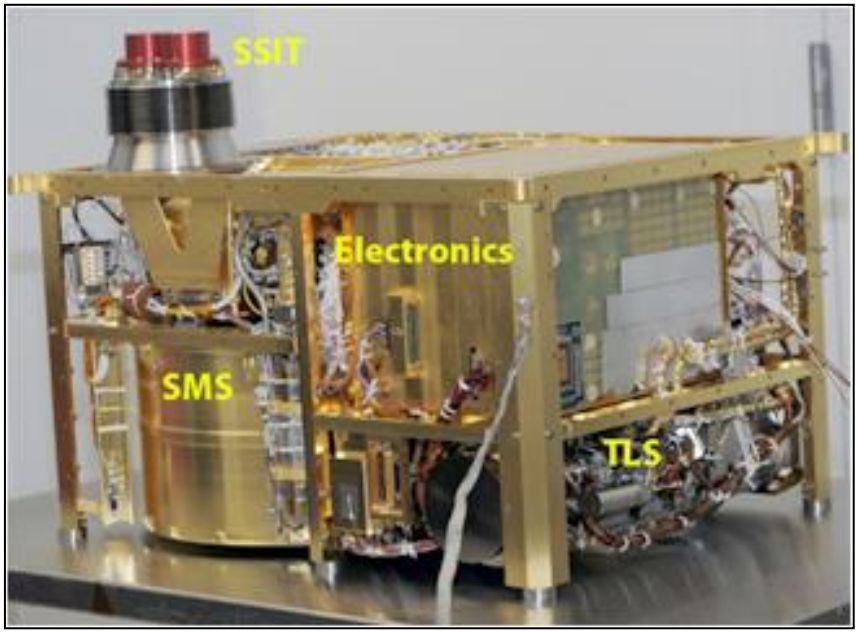
TLS spectra for CO_2 show SNR's of tens of thousands for main line

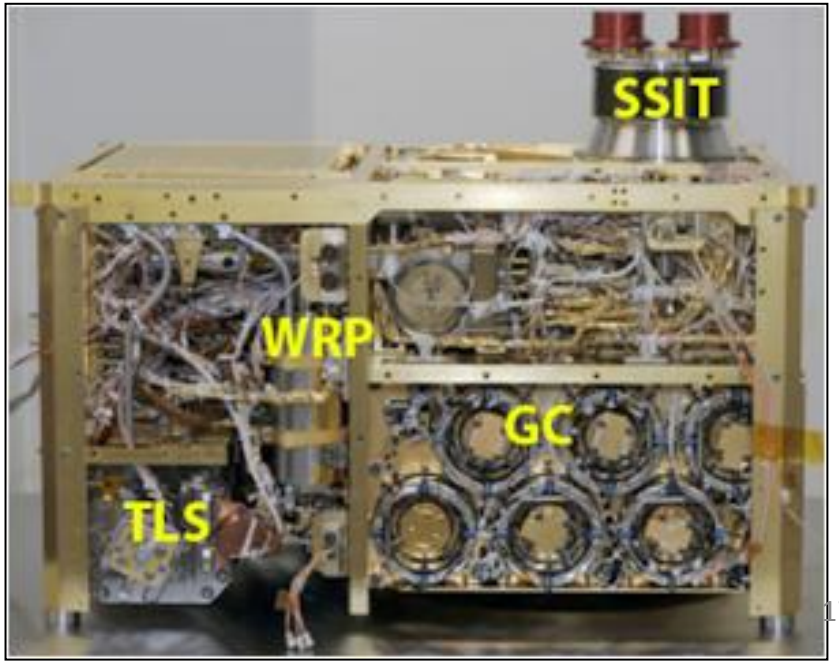
Multiple isotopes secured with two TLS IR lasers

Layout of SAM







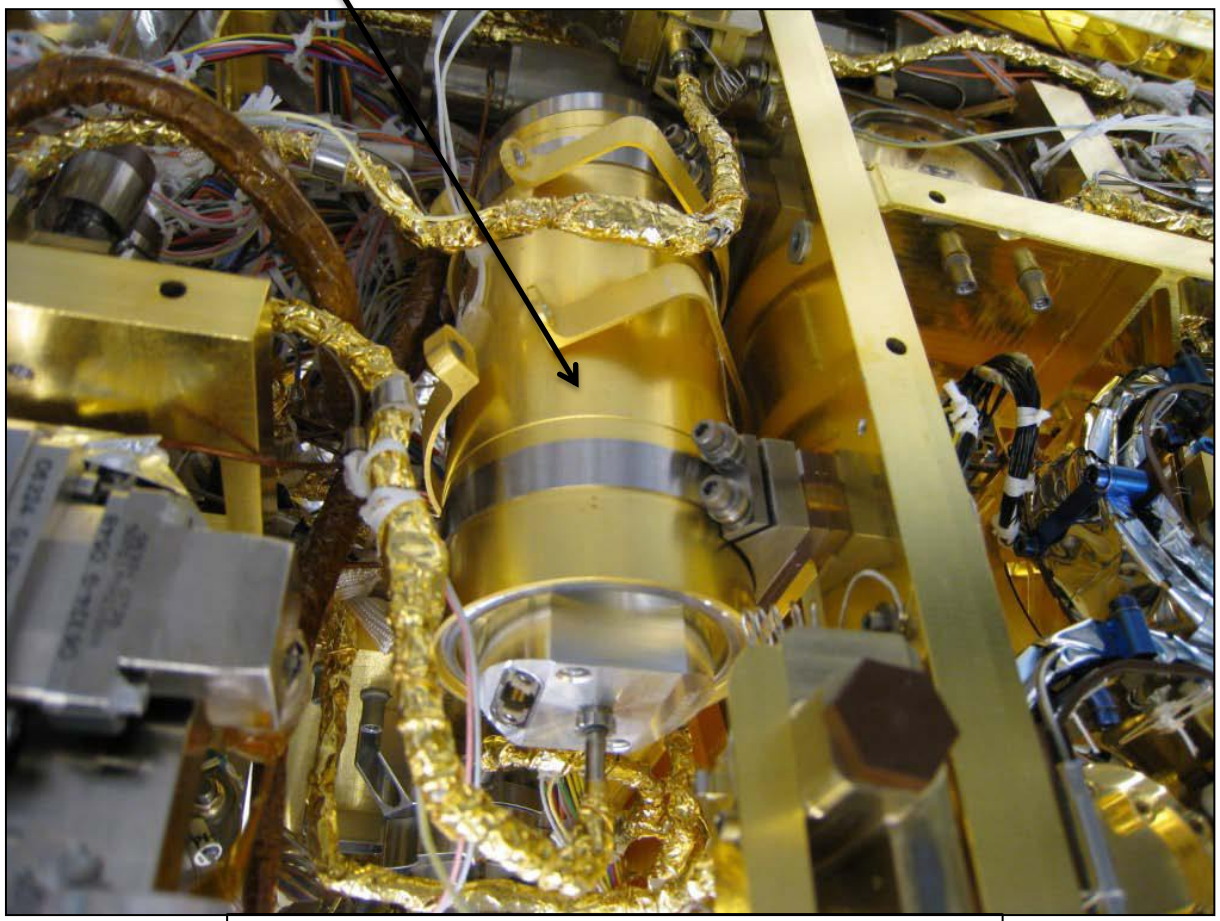


SAM Integration

Items integrated onto the SAM frame and main deck

- Quadrupole Mass Spectrometer
- Tunable Laser Spectrometer
- 6 GC columns
- Sample Manipulation System
- 2 pyrolysis cells
- 16 Gas Processing System manifolds
- 2 high conductance valves
- 52 microvalves
- 51 gas line heaters
- Combustion & cal gases
- 2 scrubbers and 2 getters
- Hydrocarbon trap
- 2 turbomolecular pumps
- 2 He tanks pressurized to ~2000 psi
- 4 heat pipes
- Electronics stack
- ~ 600 m of harness wire
- Solid Sample Inlet Tubes
- Thermal shields

Wide Range Pump (WRP1) in Suite



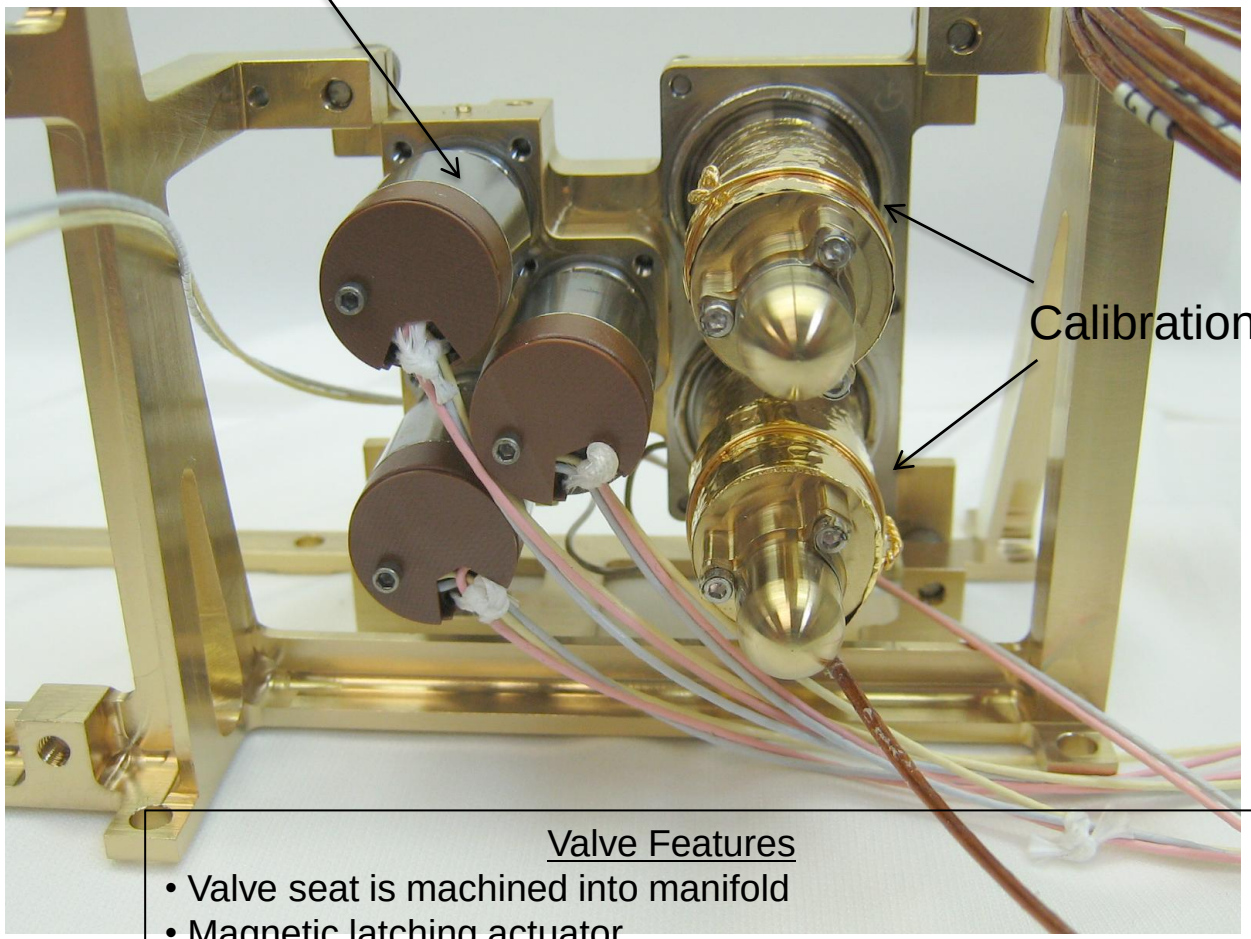
Characteristics

- Type: turbomolecular/molecular drag pump
- Mass: ~ 540 grams
- Dimensions: L=12.7 cm (5”); D= 5 cm (2”)
- Power: ~ 11W average
- Pumping Speed: ~ 5-6 l/s
- Compression Ratio for CO_2: ~ 10^8
- Maximum Exhaust Pressure: 12 torr

WRPs designed and manufactured by Creare, Inc. Hanover NH

Manifold 3 (Calibration Manifold)

GSFC In-house developed solenoid latching valves welded to manifold



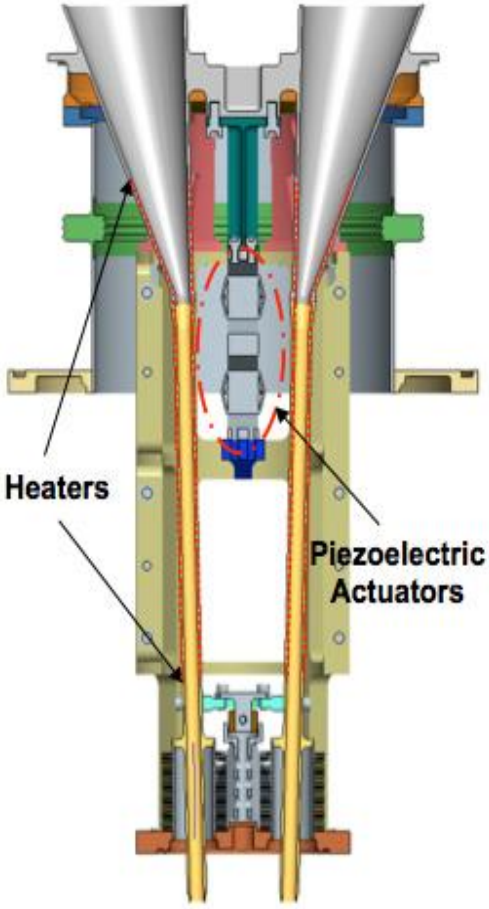
Valve Features

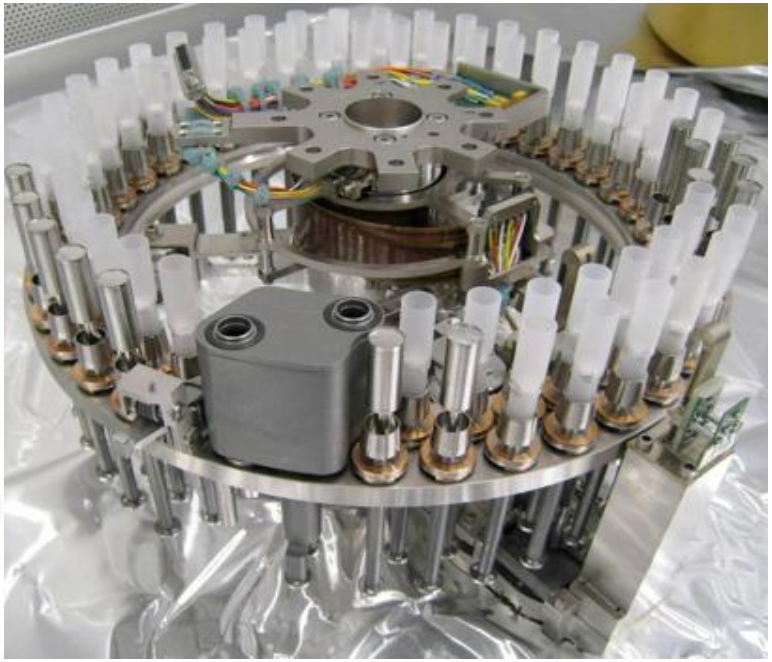
- Valve seat is machined into manifold
- Magnetic latching actuator
- L= 25mm, D= 14mm
- Mass ~ 22 grams
- Removable solenoid enabling high temperature bakeouts
- External and valve seat leaks – less than $1x10^{-10}$ atm.cc/sec-He

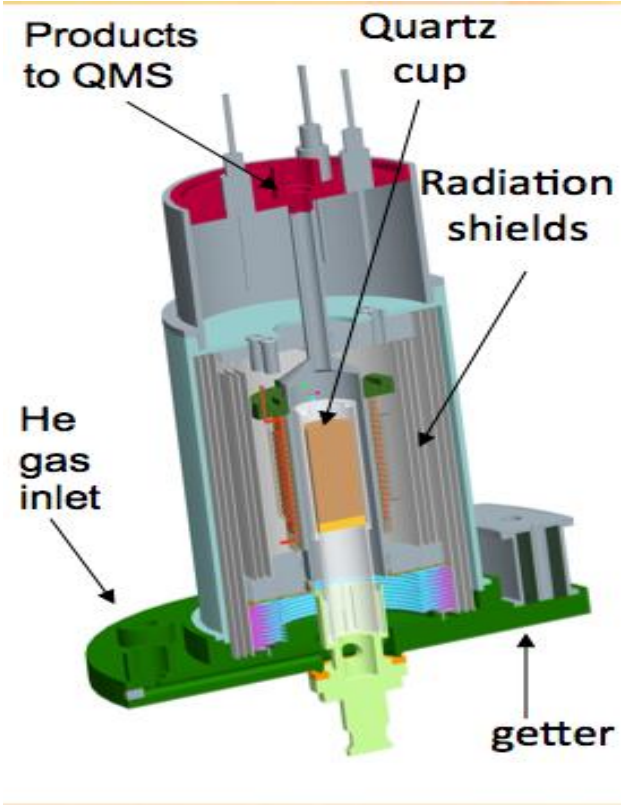
Microvalves have been licensed to Mindrum Precision for manufacturing

Solid Sample Inlet and Transport System

Two SAM inlet funnels and tubes transport sample to the SMS cups → SMS carousel with 74 sampling cups deliver sample to Pyrolysis oven → Pyrolysis oven products are transported to QMS, GC and TLS

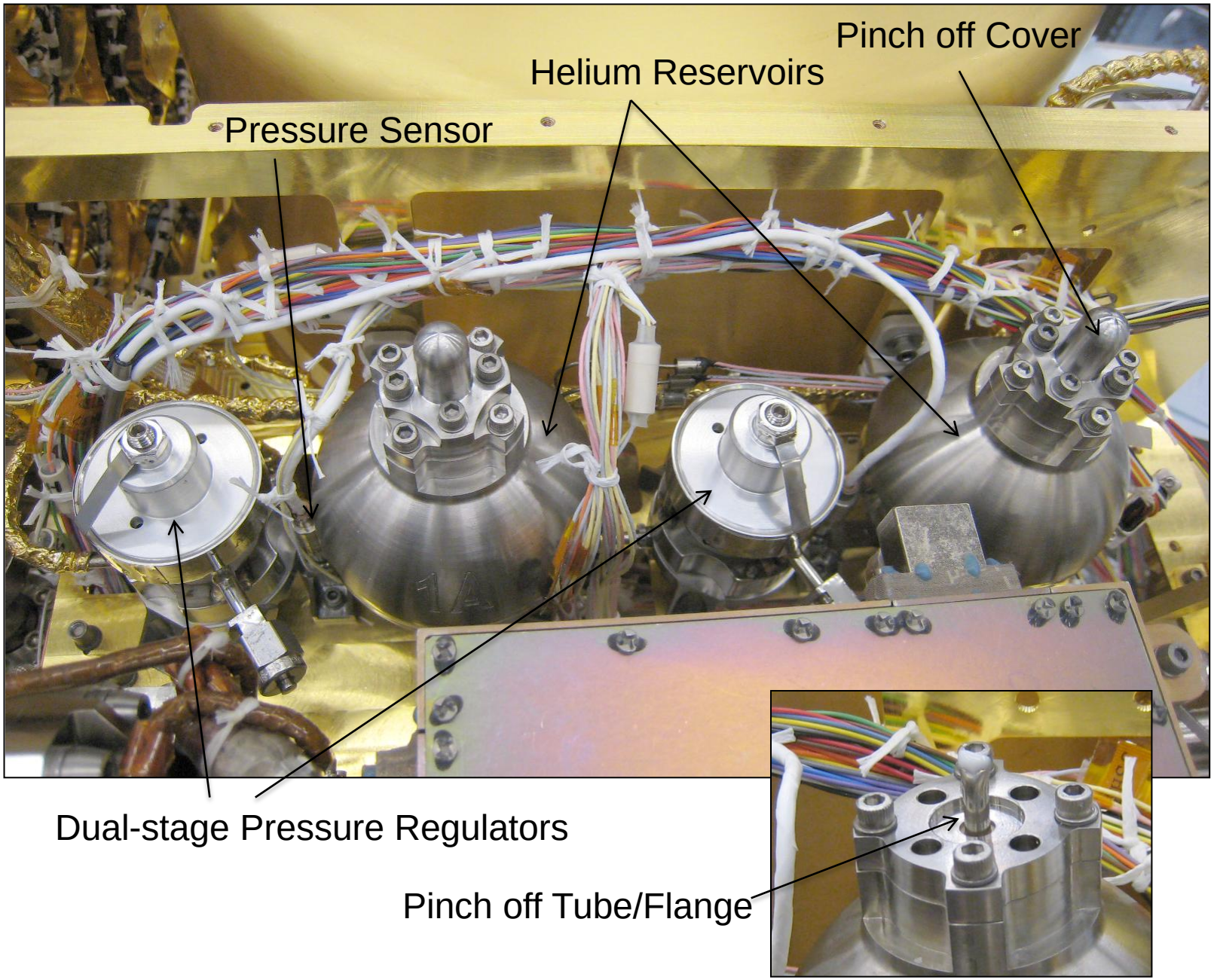






Sample Manipulation System (SMS)
Manufactured by Honeybee Robotics

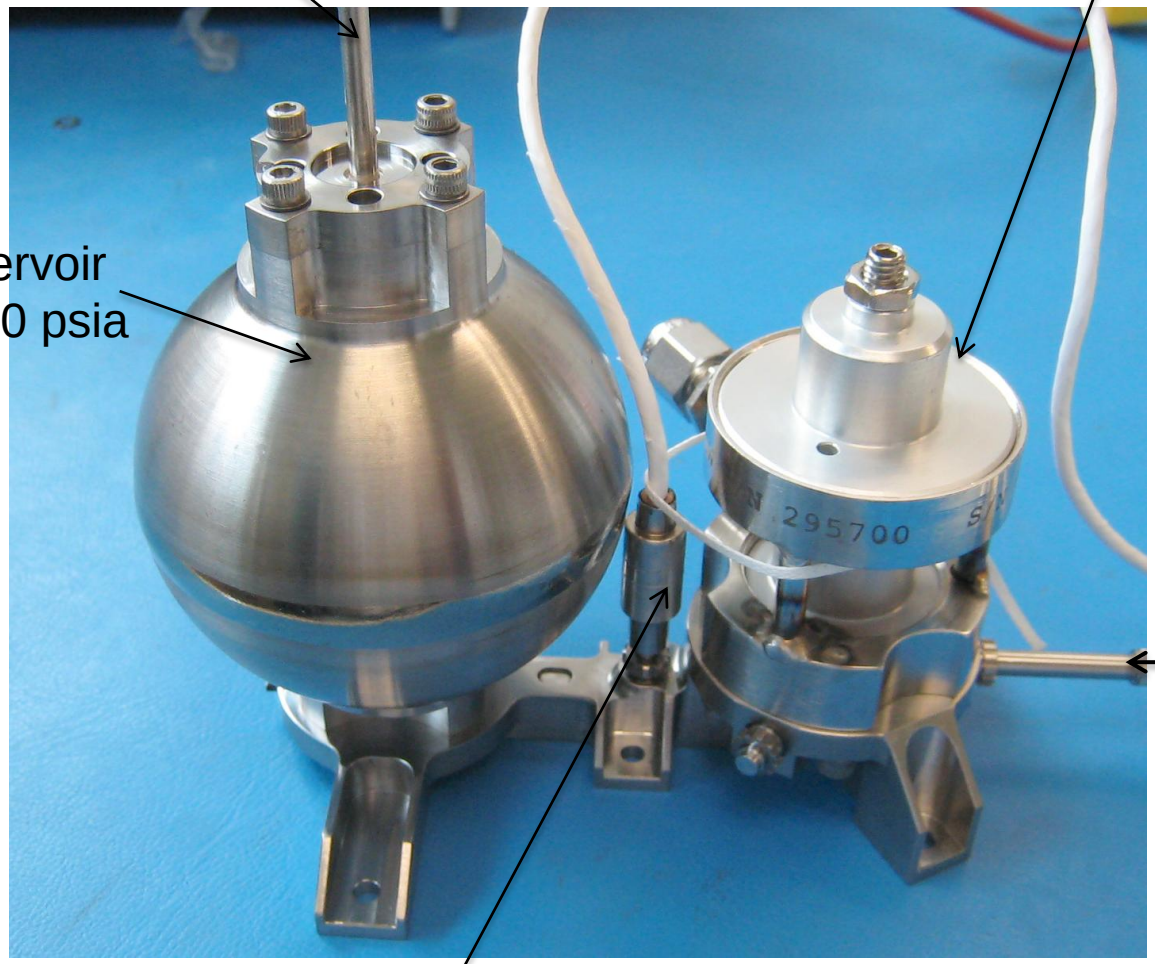
Redundant Helium Manifolds



Helium Manifold Assembly

1/8” O.D. Nickel Tubing
Pinch off Line

Dual-stage Pressure Regulator from AutoFlow Products
(outlet pressure = 1.2 bar)

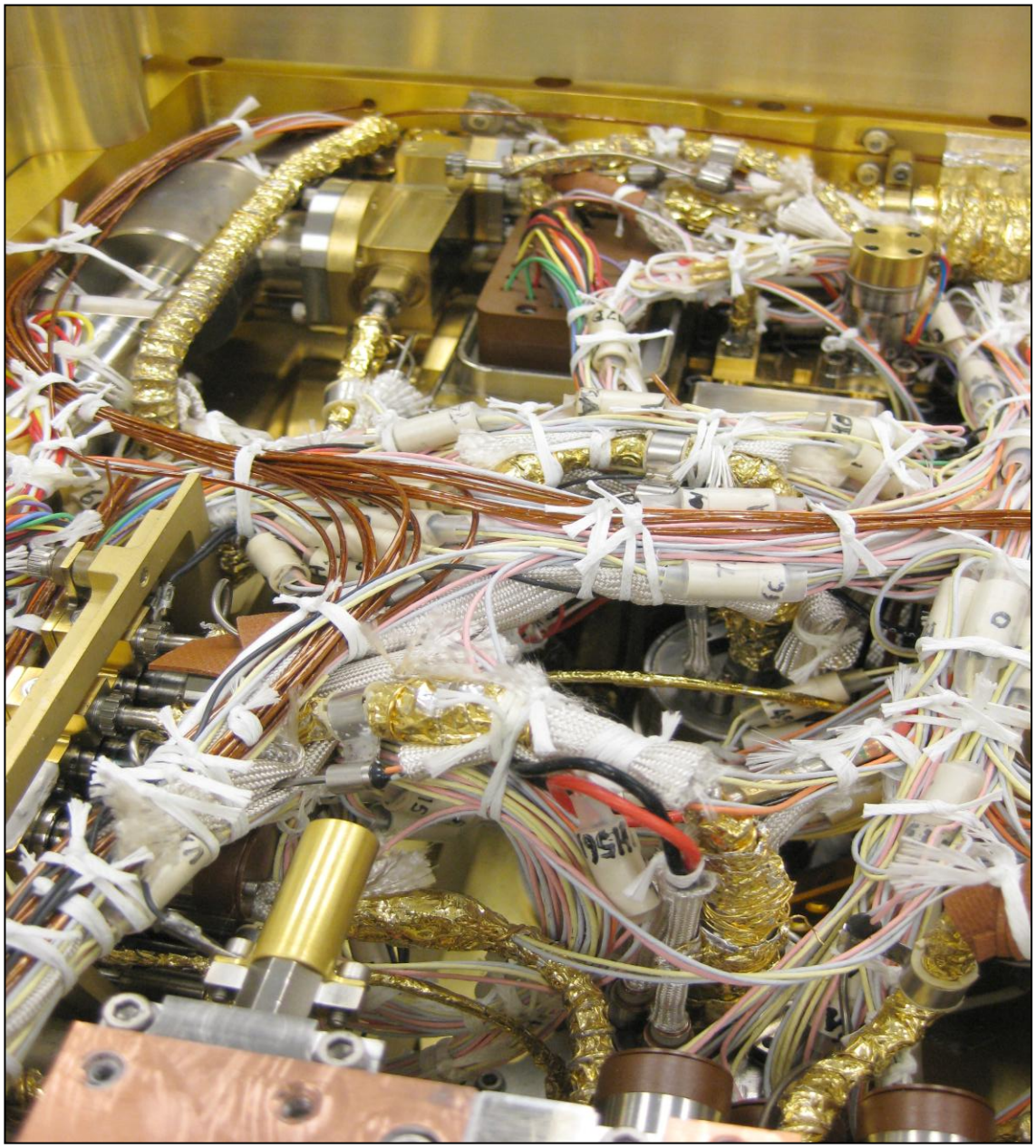


Helium Reservoir
(filled to 2300 psia

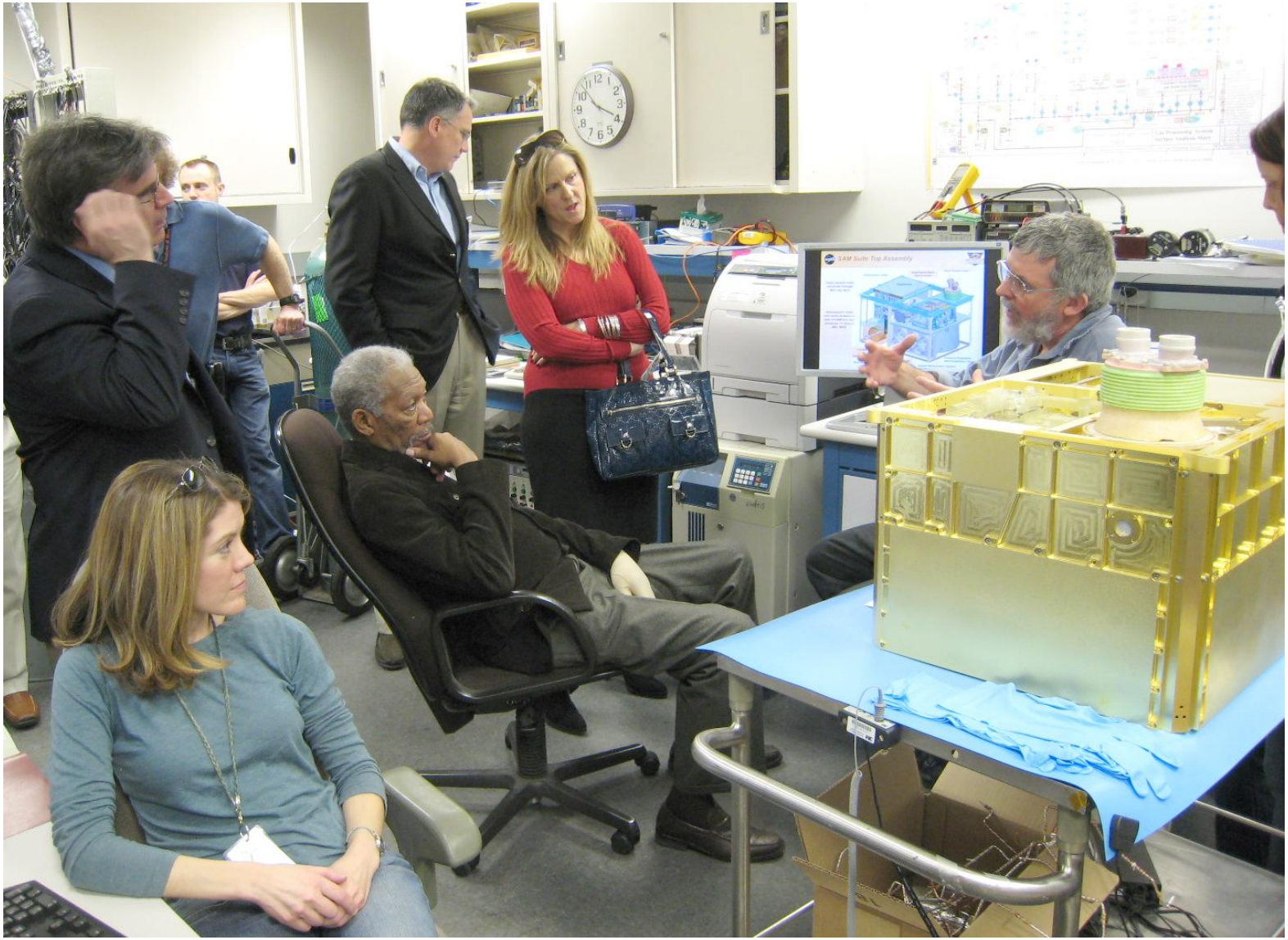
Outlet Tube to Gas Processing System

Pressure Sensor from Kulite Semiconductor

Suite Integrated with hardware and harnesses



And Sometimes We Get Visitors



Follow Curiosity on its way to Mars

http://mars.jpl.nasa.gov/msl