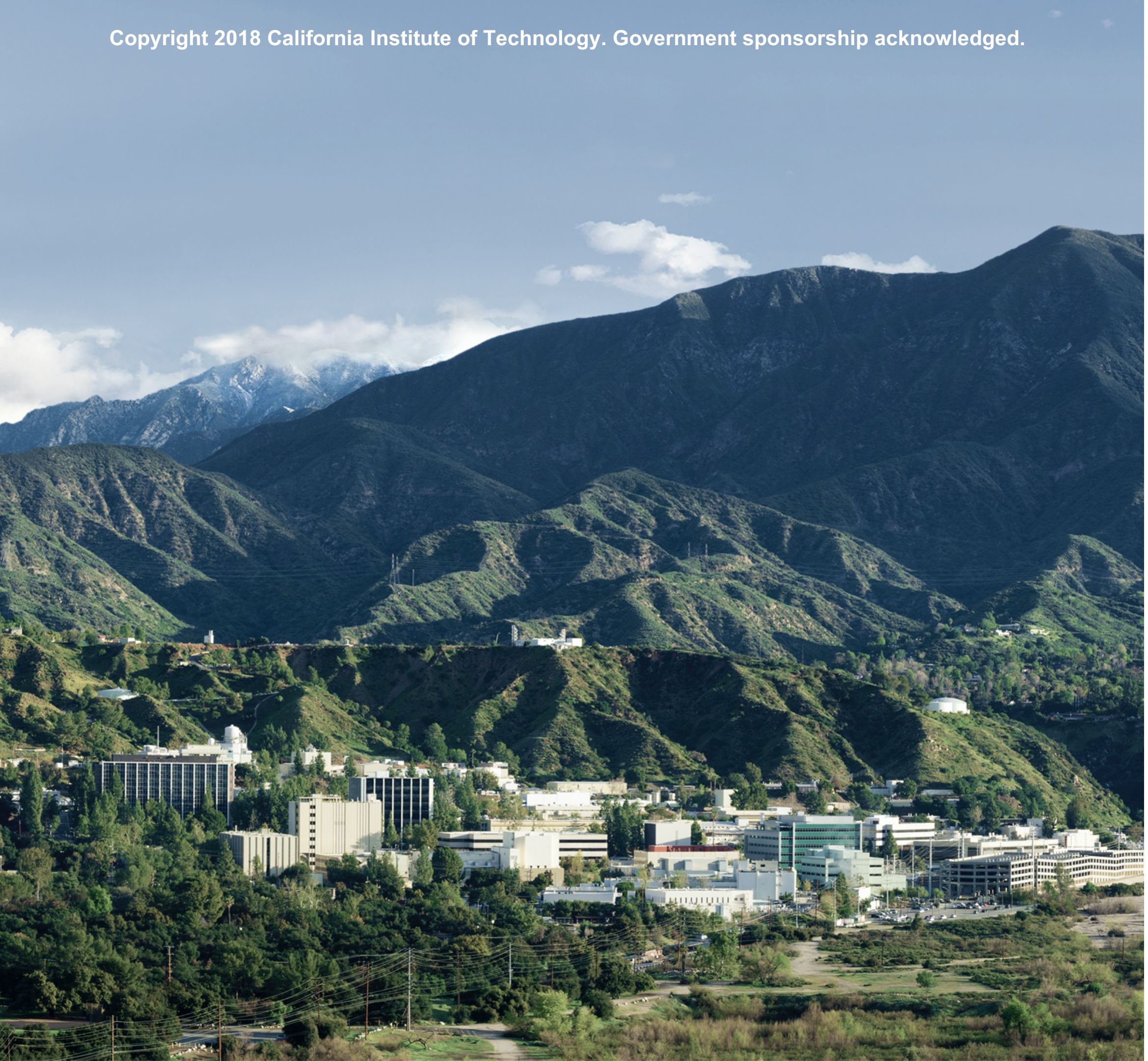


Society of Hispanic Professional Engineers (SHPE) 2018 National Conference

Psyche:

Mock Addition to a Discovery Mission

Eric Aguilar

Spacecraft Mechanical Staff

Luis Dominguez

System Integration, Test & Launch Engineering

David Henriquez

Deputy Section Manager – Flight Electronics

Paul Ramirez

Supervisor - Science Data System Operations Engineering

JPL

Jet Propulsion Laboratory

California Institute of Technology

NASA Psyche Mission: Journey to a Metal World

The NASA Psyche mission will explore, for the first time ever, a world made primarily of metal. There are many engineering challenges to developing a spacecraft to explore Psyche. The participants will be divided into teams to participate in a mock spacecraft design trade study to experience how the different engineering disciplines engage each other in developing a spacecraft.

Psyche Video

Simulation Challenge

NASA has just approved funding for $120M secondary spacecraft for the Psyche Mission. Your task, if you accept it, is to design a secondary spacecraft with a minimum of 3 science instruments with minimal impact to the primary mission.

Ground Density/Surface Topology: Unknown

Atmosphere Density: Unknown

Rotational Stability: Unknown

Magnetic Interference: Unknown

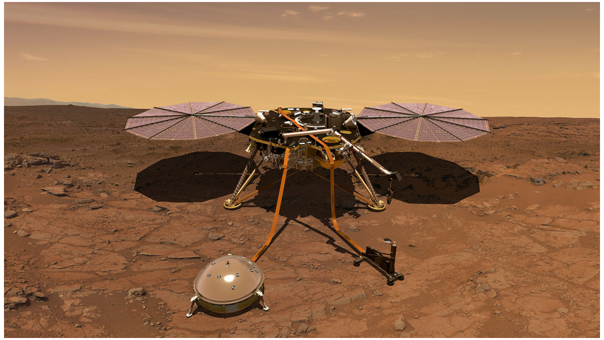
Impactor vs Lander

- Deep Impact
  - Scientific Instrument(s)
    - High-Resolution Instrument (HRI)
    - Medium-Resolution Instrument (MRI)
    - Impactor
    - Impactor Target Sensor (ITS)

Image: nasa.gov

- InSight
  - Scientific Instrument(s)
    - Seismic Experiment for Interior Structure
    - Heat Flow and Physical Properties Package
    - Auxiliary Payload Sensor Suite
    - Instrument Deployment System and Laser Retroreflector

Image: jpl.nasa.gov



Group Work

- Design your subsystem for the selected approach
- Power and Communications
  - Eric Aguilar
- GNC and Payload
  - David Henriquez
- Mechanical and Prop
  - Luis Dominguez
- Computer Science
  - Paul Ramirez

For Information on the Real Psyche Mission

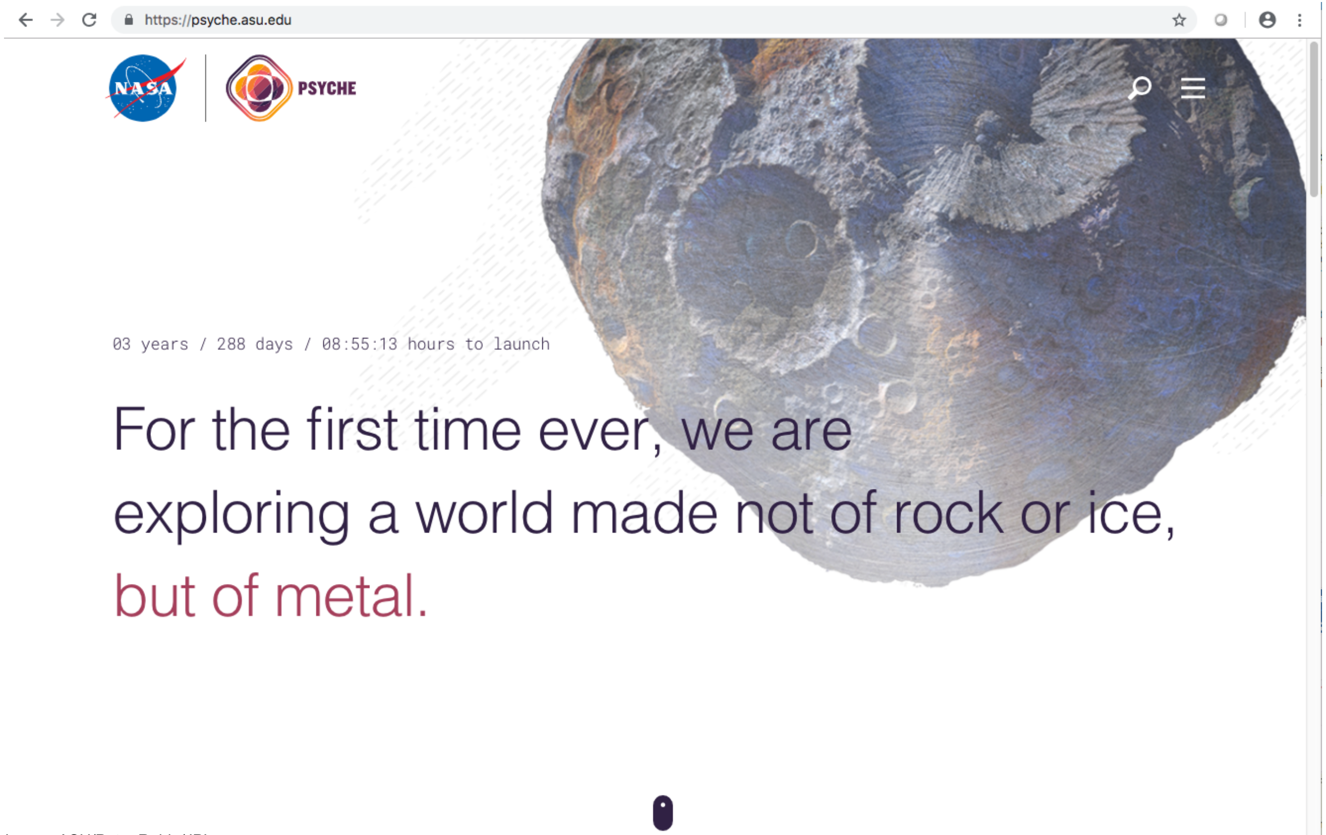


Image: ASU/Peter Rubin/JPL

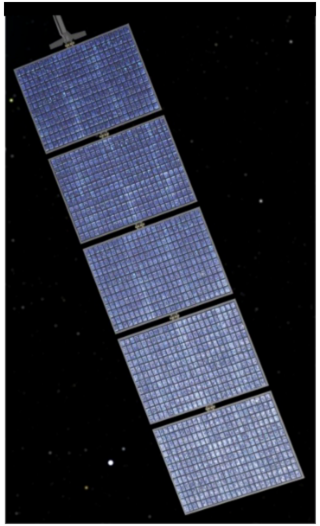
https://psyche.asu.edu/

Subsystem Considerations

Power Considerations

- Power
  - Battery
    - Battery
      - Energy storage capability
      - Mass
    - Thermal Battery
      - Energy storage capability
      - Mass
  - RTG
    - Power generation
    - Mass
  - Solar Power
    - Power generation
    - Mass

Image: jpl.nasa.gov



Solar Array

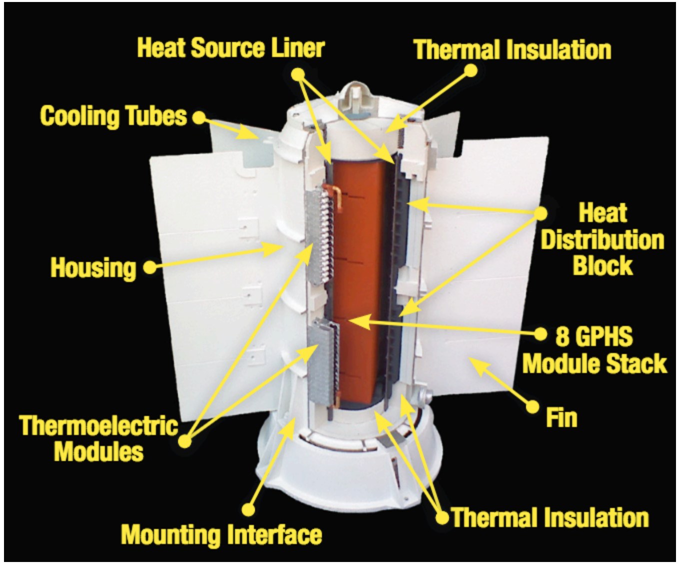
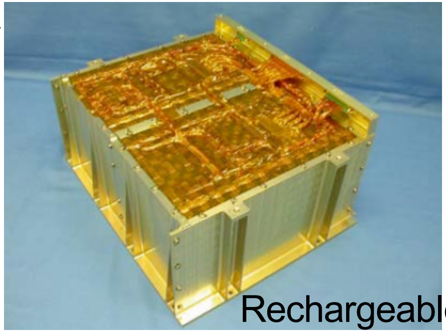


Image: mars.nasa.gov

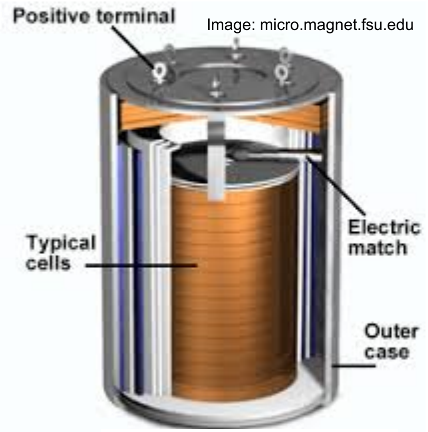
RTG

Image: jpl.nasa.gov



Rechargeable

Image: micro.magnet.fsu.edu

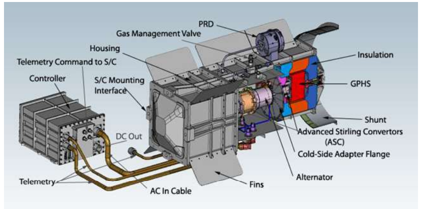


Thermal Battery

Power Options

Radioisotope Thermoelectric Generators

Advanced Stirling Radioisotope Generator

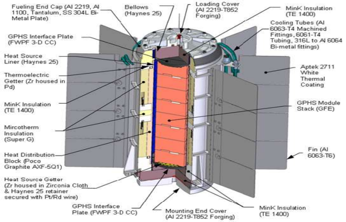


Credit: U.S. Federal Government

Instantaneous Power (W)	Stored Power (W-Hrs)
140	0

Mass (kg)	Heat (W)
34	500

Multi-Mission Radioisotope Thermoelectric Generator

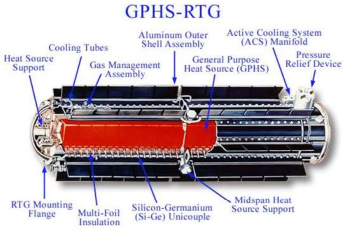


Credit: Ryan Bechtel, U.S. Department of Energy

Instantaneous Power (W)	Stored Power (W-Hrs)
100	0

Mass (kg)	Heat (W)
45	2000

General Purpose Heat Source - Radioisotope Generator



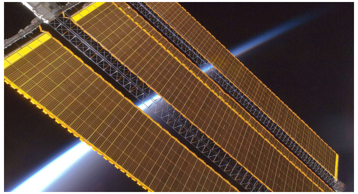
Credit: NASA

Instantaneous Power (W)	Stored Power (W-Hrs)
300	0

Mass (kg)	Heat (W)
58	4400

Solar Array Panel

Juno-Like Solar Array Panel (1m²)



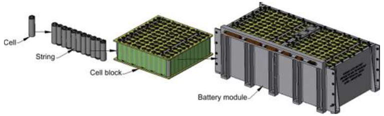
Credit: NASA

Instantaneous Power (W)	Stored Power (W-Hrs)
42	0

Mass (kg)	Heat (W)
5	0

Batteries

Rechargeable Battery Packs



Credit: ABSL Space Products/EnerSys Advanced Systems

Instantaneous Power (W)	Stored Power (W-Hrs)
336	672

Mass (kg)	Heat (W)
7	-100

Thermal Batteries

Eagle-Picher EAP-12155

Credit: Eagle-Picher Technologies

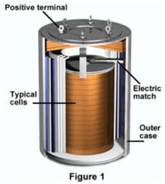


Figure 1

Credit: Florida State University/ Michael W. Davidson

Power (W)	Duration (sec)
280	200

Mass (kg)	Heat (W)
3	300

Communications and Control Considerations

- Data Rate
  - Compressed/Uncompressed
- Antenna type
  - UHF
  - Xband

Image: nasa.gov

- CPU Power
- CPU
- Thrustor control
- Gimbal interface
- Heaters
- Comm interface
- Battery Control

Mechanical & Thermal Considerations

- Mechanical
  - Primary Structure
    - Radiation environment makes lander structure significantly heavier
  - Secondary Structures
    - Structures for mounting other equipment
  - Payload Accommodations
    - Penetrator mass is large
- Thermal
  - Blanketing
  - HTR's
  - PRT's
  - Power Considerations

Artist's Concept

Image: jpl.nasa.gov

Mechanical & Thermal

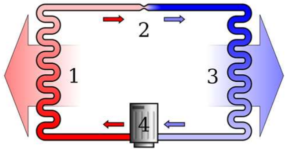
Kapton Film Heaters

Credit: Omega Engineering

Power (W/In²): -5

Mass (kg): 0.01

Heat Rejection System

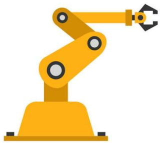


Credit: Wikimedia Commons

Power (W): -50

Mass (kg): 25

Robotic Arm



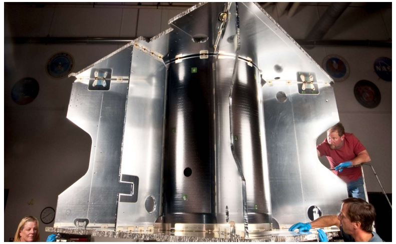
Credit: Wikimedia Commons

Power (W): -350

Mass (kg): 35

Heat (W): -150

Primary Structure



Credit: NASA/Lockheed Martin

Impactor

Mass (kg): 80

Lander

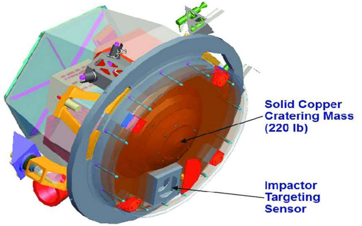
Mass (kg): 160

Secondary Structures

Mass (kg): 1 Per Component < 10kgs

Mass: 10% (% of Component Mass) Per Component > 10kgs

Impactor Mass



Mass (kg): 100

Credit: Henderson/Blume "Deep Impact – A Review of the World's Pioneering Hypervelocity Impact Mission"

GNC/Prop Considerations

- Penetrator Mass Acceleration Rocket
- Inertial Measurement Unit
- Reaction Control System
  - Position Control
    - Reaction Speed
    - Accuracy/Precision

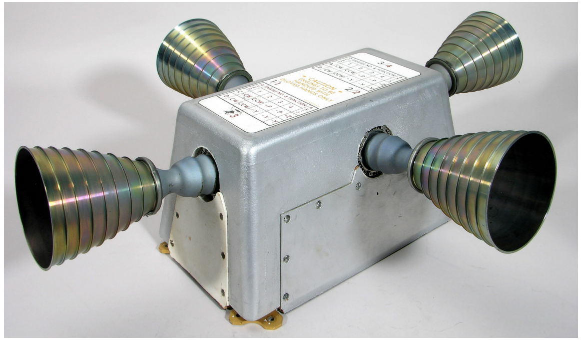


Image: airandsspace.si.edu

Image: northropgrumman.com

Image: aerospace.honeywell.com

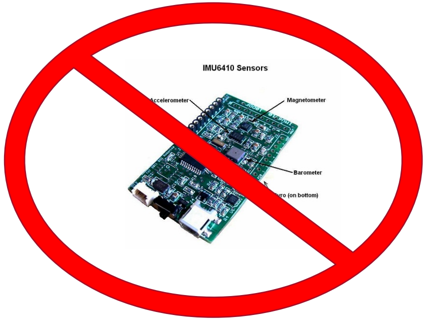


Image: Alan Shepard/NASA upload.Wikimedia.org

Guidance, Navigation, & Control

Credit: Wikimedia Commons

Credit: Wikimedia Commons

Inertial Measurement Unit

Credit: NASA

Credit: NASA

Credit: Honeywell Aerospace

Power (W)

-30

Mass (kg)

7

Star Tracker

Credit: Ball Aerospace & Technologies Corp.

Power (W)

-40

Mass (kg)

10

Reaction Control System

Credit: NASA

Credit: NASA

Credit: National Air and Space Museum - Smithsonian Institution

Power (W)

-240

Mass (kg)

20

Landing System

Credit: NASA

Credit: NASA

Credit: Alan Shepard/NASA

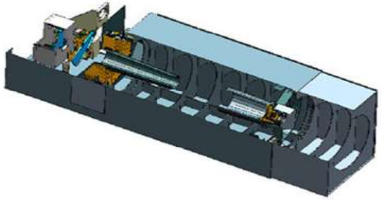
Power (W)

-600

Mass (kg)

40

Impact Targeting Sensor



Credit: University of Maryland/Ball Aerospace & Technologies Corp./NASA-JPL

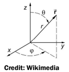
Power (W)

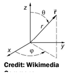
-30

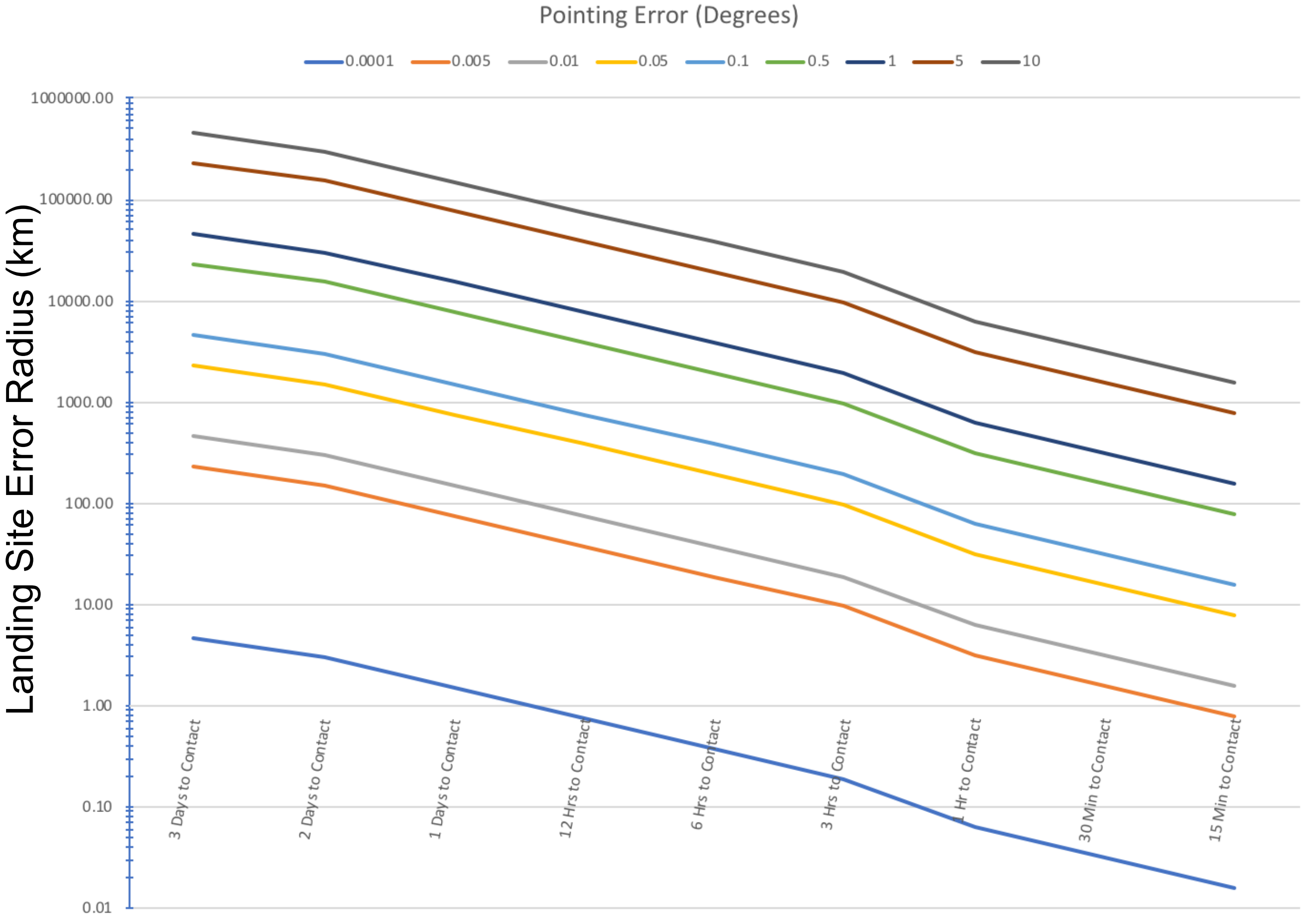
Mass (kg)

20

Guidance, Navigation, & Control







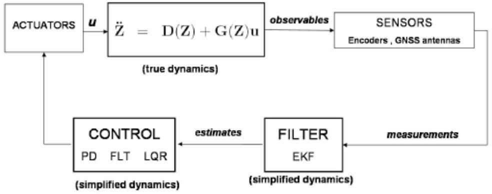
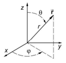
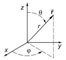


Image: https://www.researchgate.net/figure/GNC-loop-schematic_fig3_236583775


Credit: Wikimedia

Guidance, Navigation, & Control


Credit: Wikimedia

Impactor

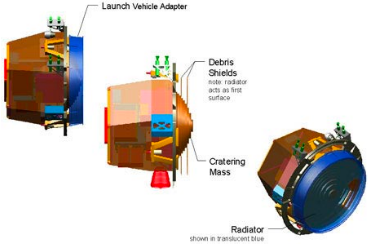


Image: NASA

- **Pointing Knowledge:** 150 μrad 3 axes 3-sigma
- **Mass:** 100 kg
- **Propulsion/RCS:**
  - 25 m/s divert; 1750 N-s RCS impulse
  - Uses 4 Hydrazine Thrusters
  - Four 22 N thrusters firing in pulses varying in length from .015 to 0.5 second each.
- **Telecom Band:**
  - S-Band 64 Kbps
- **Mission Duration:** 24 hr

Lander

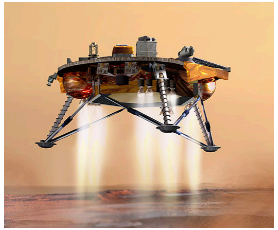


Image: NASA

- **Pointing Knowledge:** 150 μrad 3 axes 3-sigma
- Mass: 350 kg
- **Propulsion/RCS:**
  - Uses 20 Hydrazine Thrusters
  - Twelve 293 N thrusters control descent
  - Four 15.6 N thruster for TCM
- **Telecom Band:**
  - UHF rates to 8 Kbps to 128 Kbps
  - X-Band 2.0 Kbps
- **Mission Duration:** 2,208 hr

Payload

Impactor

- **Mission Duration:** 24 hr
- **High Resolution Instrument (HRI) – Ball Aerospace**
  - Telescope with a 30 cm aperture, 10.5 m focal length, 2 mrad FOV
  - Infrared (IR) spectrometer, and a multi-spectral CCD camera
  - 2 m per pixel at 700 km
- **Medium Resolution Instrument (MRI) – Ball Aerospace**
  - Backup for the (HRI)
  - Telescope with a 12 cm aperture, 2.1 m focal length, 10 mrad FOV
  - Visible spectrum CCD camera
  - 10 m per pixel in the visible spectrum at 700 km
- **Impactor Targeting Sensor (ITS) – Ball Aerospace**
  - Primary targeting camera.
  - A duplicate of the MRI but without the filter wheel, the ITS will be used to navigate the impactor to the comet.

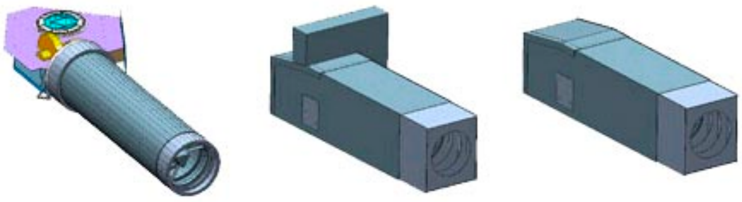


Image: NASA/JPL

Payload

Lander

Mission Duration: 2,208 hr

Robotic Arm (RA) – JPL

- 2.35 meters long with an elbow joint in the middle, allowing the arm to trench about 0.5m; to scope material into the TEGA & MECA

Microscopy, Electrochemistry, and Conductivity Analyzer (MECA) – JPL

- A Wet Chemistry Lab for characterizing the soil samples by dissolving small amounts of soil in water, to determines the pH, the abundance of minerals such as magnesium and sodium cations or chloride, bromide and sulfate anions, as well as the conductivity and redox potential. Looking through a microscope, MECA examines the soil grains to help determine their origin and mineralogy.

Robotic Arm Camera – U of Arizona and Max Planck Institute, Germany

- Mounted just above the scoop on the RA, the instrument provides close-up, full-color images of surface in the vicinity of the lander, prospective soil samples in the trench dug by the RA.

Surface Stereo Imager (SSI) – U of Arizona

- High-resolution, stereo, panoramic images of the landing site

Thermal and Evolved Gas Analyzer (TEGA) – U of Arizona & U of Texas, Dallas

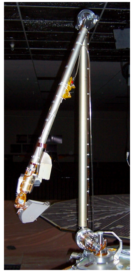
- A high-temperature furnace and mass spectrometer instrument to analyze soil samples.

Mars Descent Imager (MARDI) - Malin Space Science Systems

- Provides hi-res images of the topology around the landing zone

Meteorological Station (MET) – Canadian Space Agency

- Records temperature, pressure and light detection; includes a ranging (LIDAR) instrument.



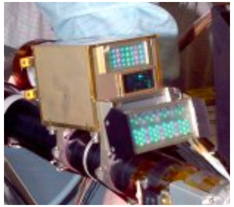


Image: NASA/JPL

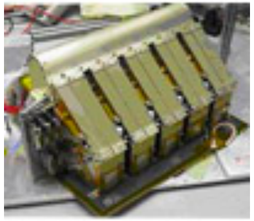


Image: U of Arizona & U of Texas, Dallas

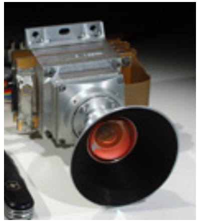


Image: Malin Space Science Systems

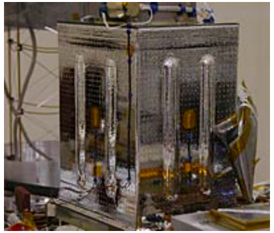


Image: Canadian Space Agency

Image: U of Arizona

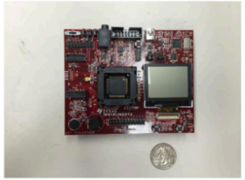
Software Considerations

Flight

- Common Components
  - Command dispatching/sequencing
  - Telemetry processing & storage
  - Ground interfaces
  - File Uplink and Downlink
- Specific Hardware
  - Device drivers
  - Operating system adaptations
  - Guidance, Navigation and Control (GNC)
  - Radios

Processing Constraints

- Real Time, Near Real Time, Offline or Batch
- Automated, Autonomous or Human
- Hardware Availability
  - Memory
  - CPU
  - GPU



TI MSP430
- 24K RAM
- 64K Flash

Rack Mount PC
- Quad-core Xeon
- 8GB RAM
- Hard disk

Image: https://github.com/nasa/fprime/blob/master/docs/Architecture/FPrimeArchitectureShort.pdf

Flight Software

BAE RAD750

- Memory 128 MB SDRAM, 256 kB SUROM
- Radiation-hardness Total dose: >100 Krad (Si)
- Performance >260 Dhrystone 2.1 MIPS at 132 MHz
- Power dissipation <10.8 W
- Rail temperature range -55°C to +70°C

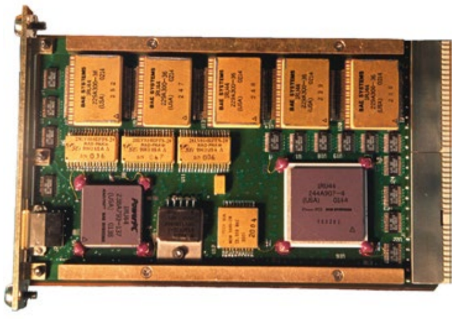


Image: BAE Systems

Cobham UT700

- Memory 64MB SRAM, 32MB MRAM
- Radiation-hardness Total dose: >100 Krad (Si)
- Performance 95 Dhrystone MIPS at 132MHz
- Power dissipation 7.3 W Max
- Qualification level -35°C to +80°C

Image: Cobham

Ground Software

Tactical

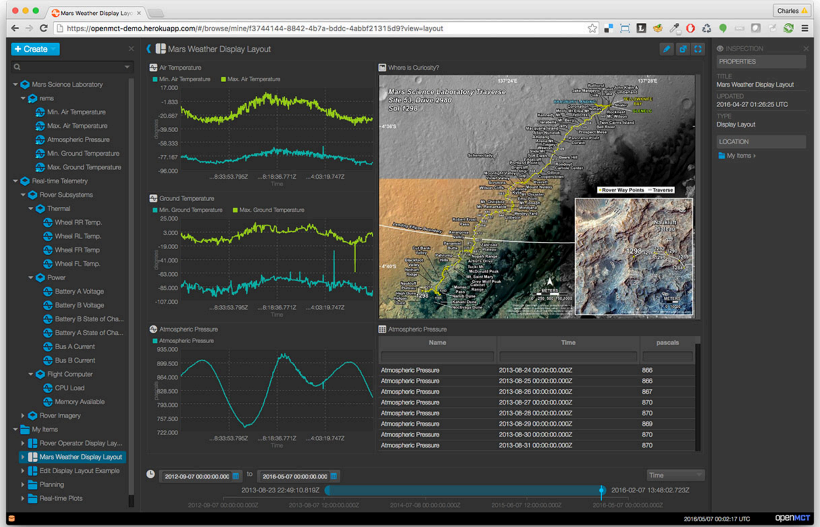


Image: https://nasa.github.io/openmct/static/res/images/Open-MCT.Browse.Layout.Mars-Weather-1.jpg

Planning

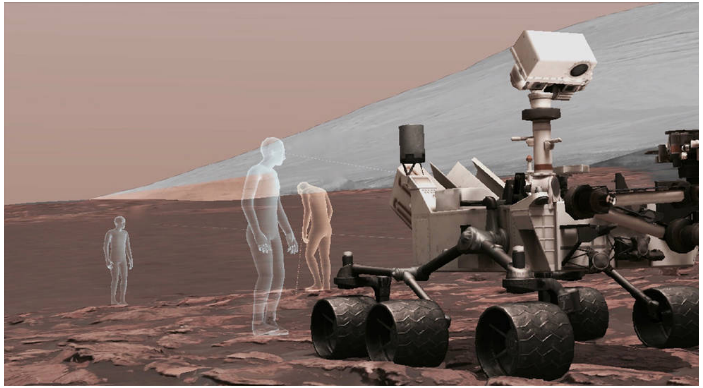


Image: https://www.nasa.gov/sites/default/files/styles/full_width/public/thumbnails/image/onsight20181002b-16.jpg?itok=wjewaKOQ

Reconstruction or Simulation

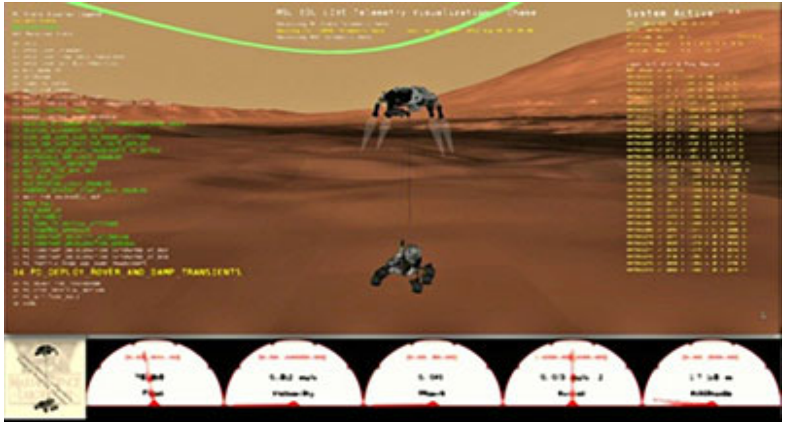


Image: https://www-robotics.jpl.nasa.gov/images/EDLgui-br.jpg

JPL

Jet Propulsion Laboratory
California Institute of Technology