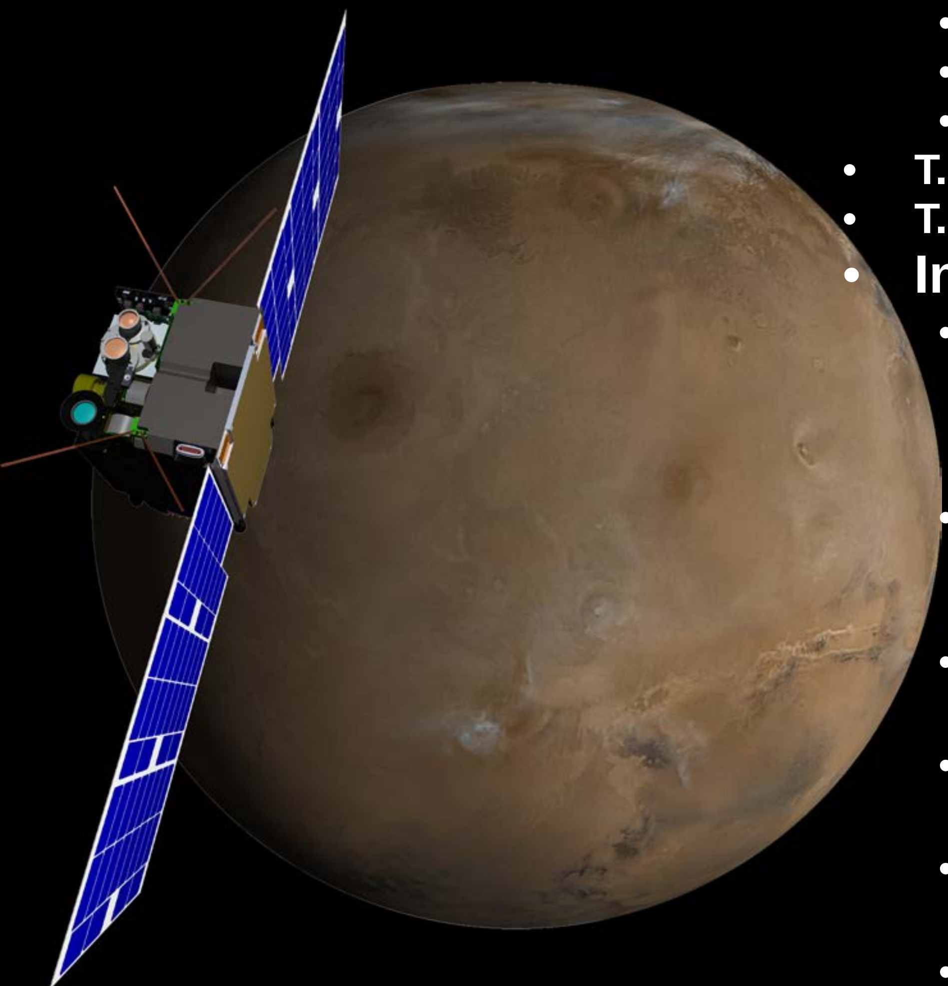
Malin Space Science Systems

STELLAR EXPLORATION

Mars Micro Orbiter (MMO)



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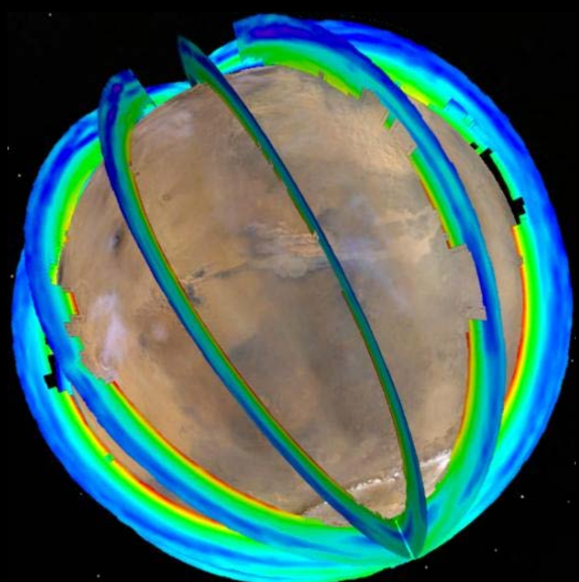
- T. Svitek (Stellar Exploration) Sys Engineer
- Institutions and Responsibilities
  - Malin Space Science Systems
    - Project Management, Payload, Avionics, Software, Attitude Control System, Mechanical Design, Solar Panels
  - Stellar Exploration
    - System Engineering, Propulsion, Telecom, Power Management/storage
  - Space Exploration Engineering
    - Mission Design & Trajectory Analysis
  - TZero, Inc.
    - Launch Service Support Engineering
  - Advanced Solutions, Inc.
    - ACS/GNC & Flight Software Support
  - Goddard Space Flight Center
    - Technical advice, guidance, peer review

Mission Objectives

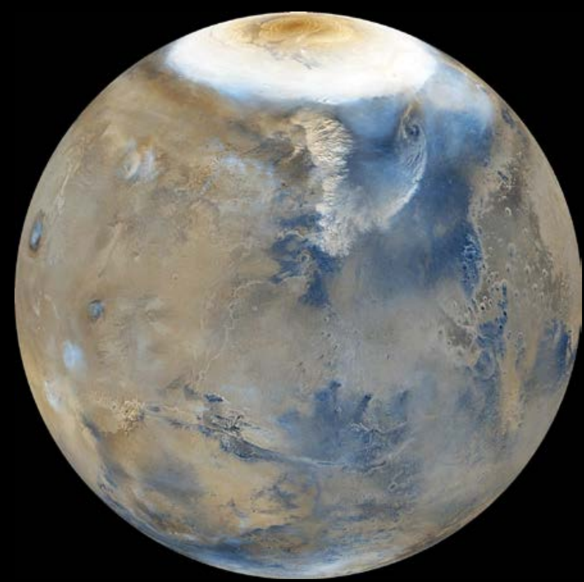
- **Level 1 Requirements**
  - **Get into Mars Orbit**
  - **Acquire science data (visible and thermal IR imaging from Mars orbit**
  - **Demonstrate Telecom Relay for Landed Assets**
- **Science Objectives**
  - ***Extend the temporal coverage of the global synoptic meteorological record (atmospheric thermal structure, dust and condensate clouds, and seasonal and perennial polar cap behavior).***
  - ***Characterize the dynamics and energy budget of the current Mars atmosphere.***
- **Key Observations**
  - **Diurnal (Temporal) coverage,**
    - ***Obtain diurnal coverage not obtained since Viking IRTM.***
    - ***Obtain more spatial and diurnal coverage of planet each season than Viking.***
  - **Polar (Spatial) coverage,**
  - **Global Spatial coverage (to a slightly lesser extent than polar coverage)**

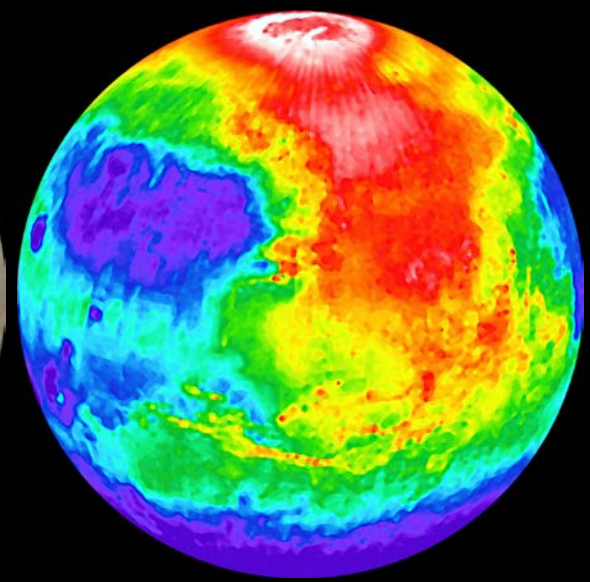
Diurnal & Seasonal Coverage Optimized by 55° high altitude orbit

- **Diurnal coverage is provided by orbit inclined by 55 deg.**
  - **Diurnal coverage shifts about 2 hours per month.**
  - **Full temporal coverage takes about 5 months, but we obtain multiple days of coverage during that period, exceeds the minimum science requirement of 2 observations at each hour at each location on the planet per season.**
  - **Good high latitude coverage.**



Current (MARCI+MCS)

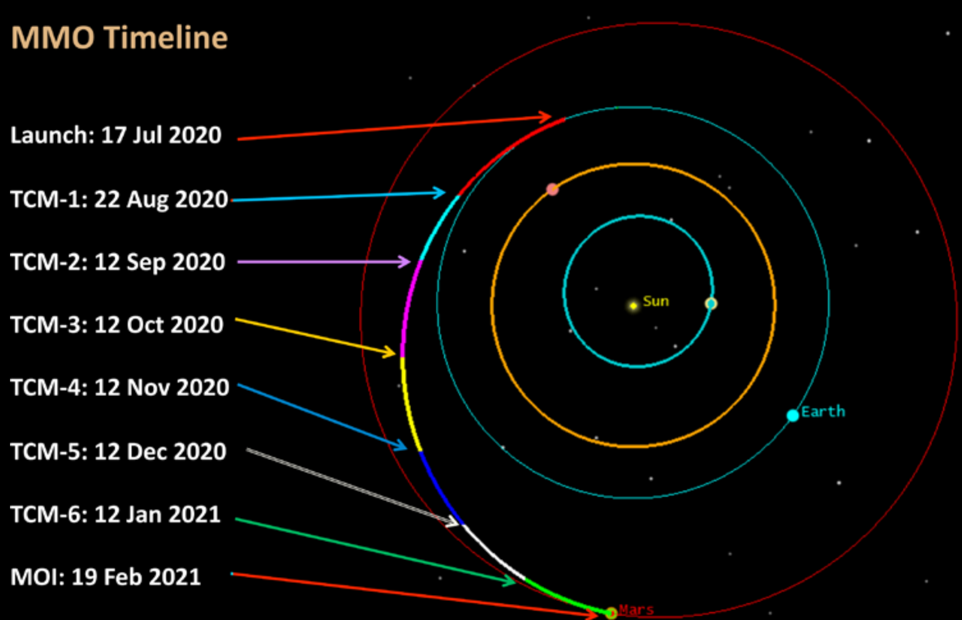


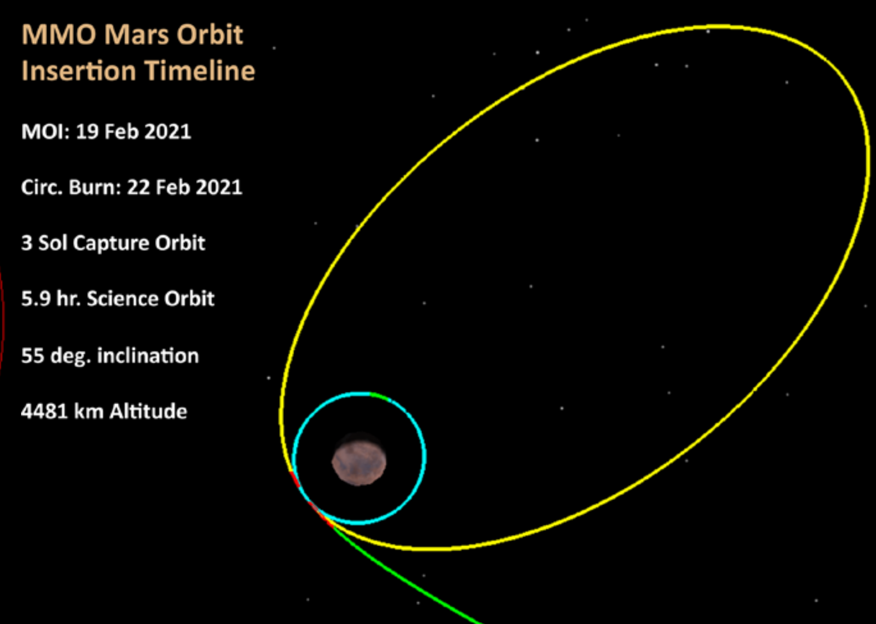


MMO

Mission Design & Trajectory

- Launch on 2020 Atlas V on 17 July 2020
  - Weekly tracking uses ΔDOR, 4-6 TCMs
  - Arrives 19 Feb 2021, will be phased with 2020 entry
- Orbit
  - 55° inclination, 4481 km altitude, with a period of 5.9 hr (advances 15° each sol) relative to surface
  - MOI ΔV ~1200 m/s (40 min burn) + 780 m/s circularization





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Science Filters

	Purpose	Spectral Range (µm)	Spectral Range (cm^{-1})	FWHM (µm)
Visible RGB Camera	**Condensate Cloud, Surface Ice, and Water Ice Aerosol Optical Depth**	0.450		~ 0.050
Visible RGB Camera	**Dust and Water Ice Optical Depth**	0.530		~ 0.050
Visible RGB Camera	**Dust Storms, Surface Ice, Dust Aerosol Optical Depth**	0.600		~ 0.050
IR Camera 1	**Surface Temperature** (Most transparent part of atmosphere)	7.93	1261	~ 1
IR Camera 1	**Dust Aerosol Optical Depth** (Atmospheric Dust Absorption band)	9.35	1069	~ 1
IR Camera 1	**Water Ice Aerosol Optical Depth** (Atmospheric Water Ice Absorption band)	11.79	848	~ 1
IR Camera 2	**Atmospheric Temperature (0-20 km)**	14.12	708	~ 0.60
IR Camera 2	**Atmospheric Temperature (10-30 km)**	14.39	694	~ 0.62
IR Camera 2	**Atmospheric Temperature (20-40 km)**	15.00	666	~ 0.67

Infrared Atmospheric CO_2 [14 μm] Altitude Weighted Bandpasses

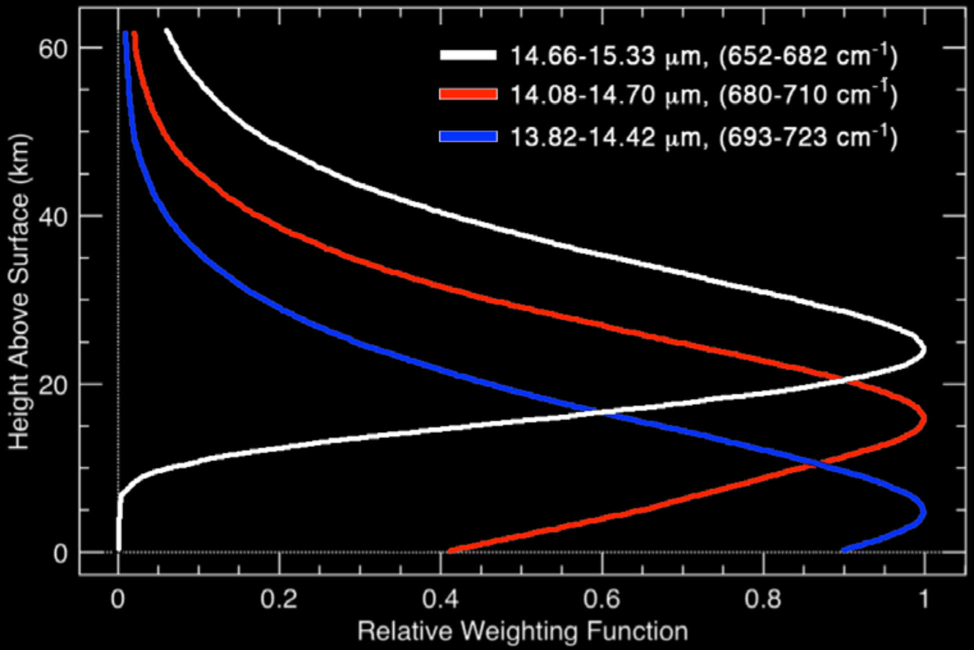
To distinguish the vertical profile of dust and water ice condensate on the limb and to cover the entire diurnal cycle, we placed “hard requirements” (minimum requirement) for:

- Three-point thermal profile
- Limb scale ≤ ~ 15 km

Orbits meet scale requirement.

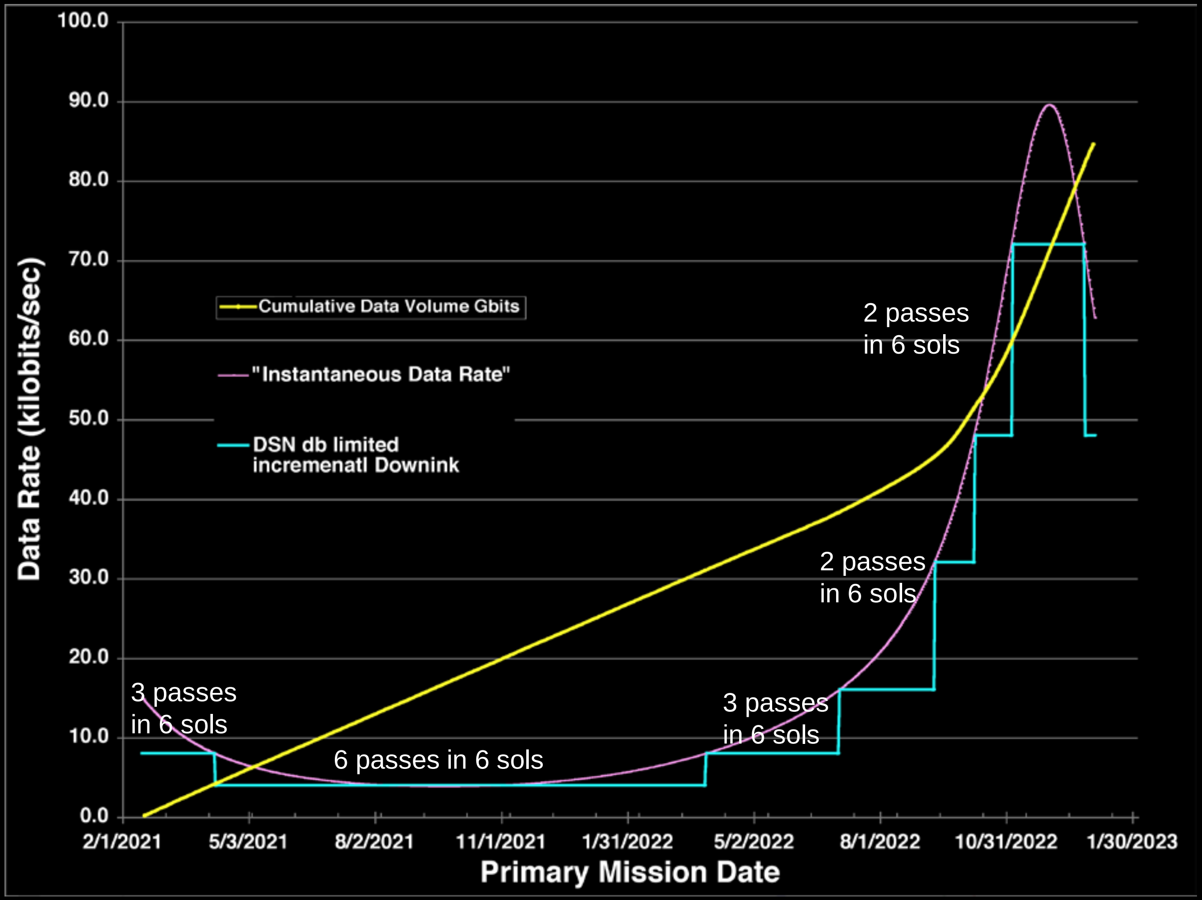
<u>Other IR Camera Requirements</u>

- Temperature Sampling: 140–305 K
- SNR = 0.02 $W/m^2/sr$
- Two-point Calibration consisting:
  1.) Onboard temperature target
  2.) Empty space imaging



Improve SNR, use creative summing scheme (along areas of constant altitude) to preserve limb resolution.

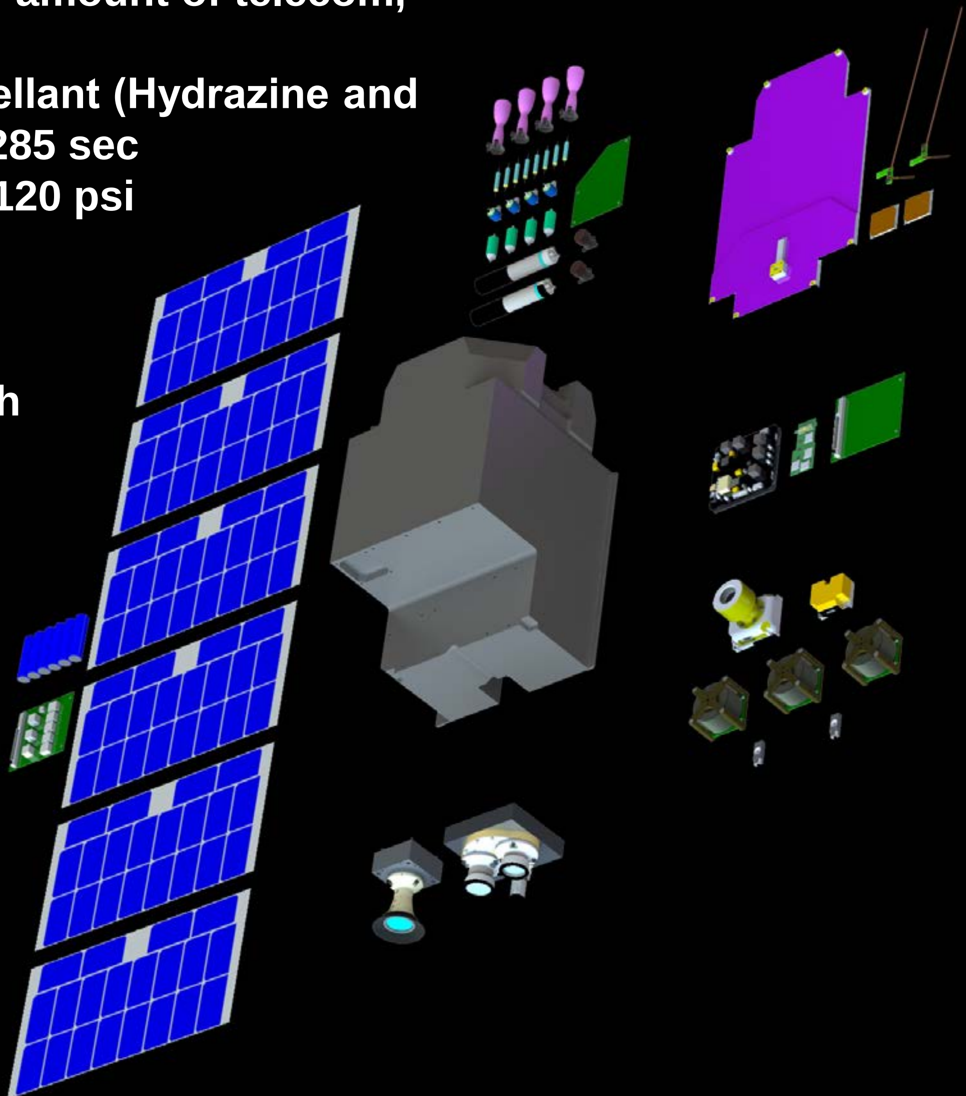
Example Mission Data Return



- **Representative Mission data return**
  - **Pink curve is spacecraft downlink range dependent downlink bit rate (kbps)**
  - **Light Blue curve is hypothetical DSN downlink profile as function of bit rate (kbps)**
  - **Yellow curve is hypothetical mission total data volume as function of tailored DSN pass allocation and bit rates**
  - **Mission total bits = 87.34 Gb**

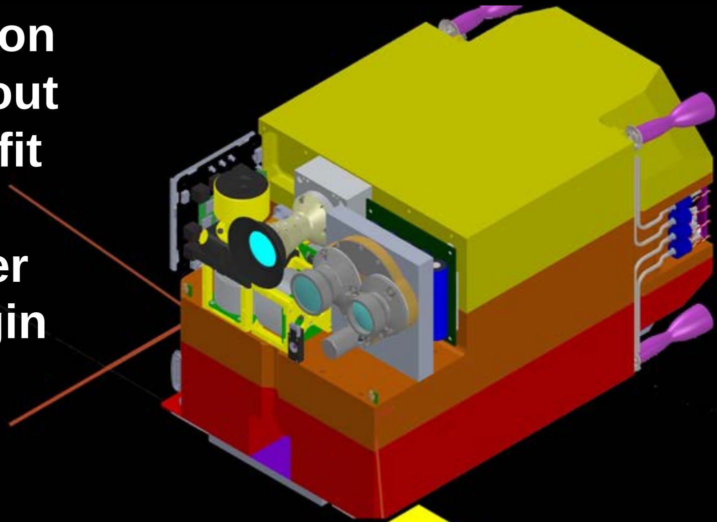
Spacecraft Subsystems

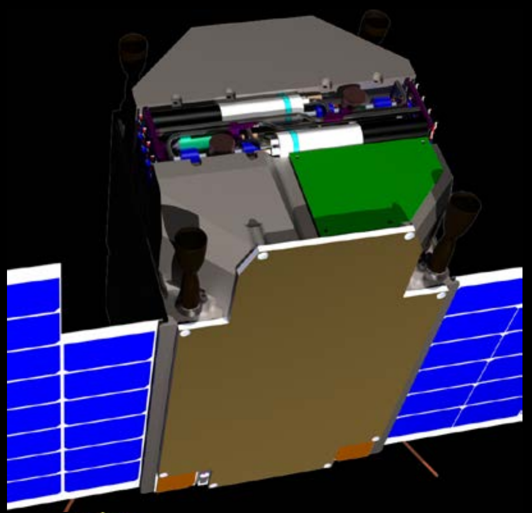
- **Primarily a propulsion system with a small amount of telecom, avionics, power, and science**
  - **≥ 80% of volume ~16.4 kg mass is propellant (Hydrazine and Nitrogen Tetroxide (NTO-MON3); ISP ~ 285 sec**
  - **Pump-pressurized, four 3 Nt thrusters, 120 psi operating pressure**
- **Remaining ~2U includes ~**
  - **3 MSSS cameras (C-50 and IR3A)**
  - **8 position filter whe el (MSL-derived) with two calibration positions**
  - **Xilinx Zinq 7045 1600 MIPS processor**
  - **2 TBytes of Mass Storage (5 x 400 GB µSD cards)**
  - **3 Software Defined Radios (SDRs)**
  - **1 power and 1 propulsion system management boards**
  - **Antennas for Ka-band for downlink to Earth, S-band up/down for command-ing and tracking, and UHF for relay**
  - **3 Reaction Wheels, 1 star camera, 2 sun sensors, 1 IMU (MEMS)**
  - **2 solar panels with 3 arrays/panel**

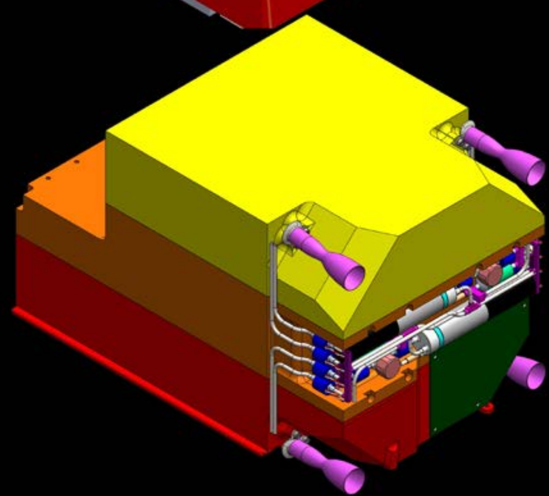


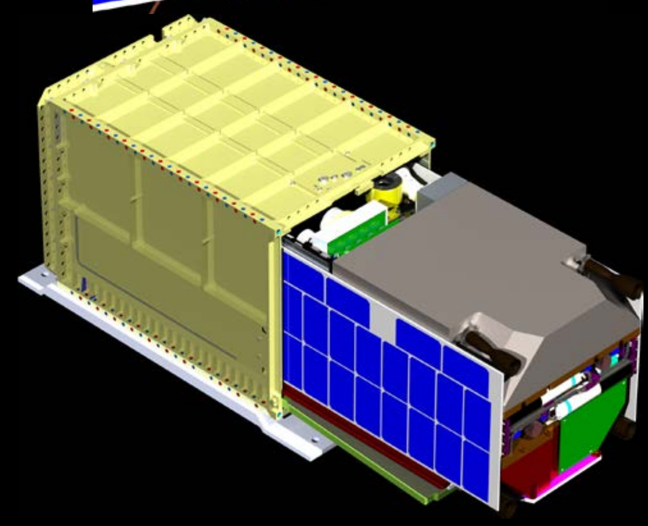
Packaging

System is limited by volume capacity of Dispenser. 12U is actually ~17.6 liters; S/C dry Mass including propulsion hardware and tanks is ~13.4 kg, wet mass is ~30 kg. Launch mass including dispenser and vibration isolation mounting is about 36 kg. 2 would fit on Centaur Aft Bulkhead Carrier with small margin



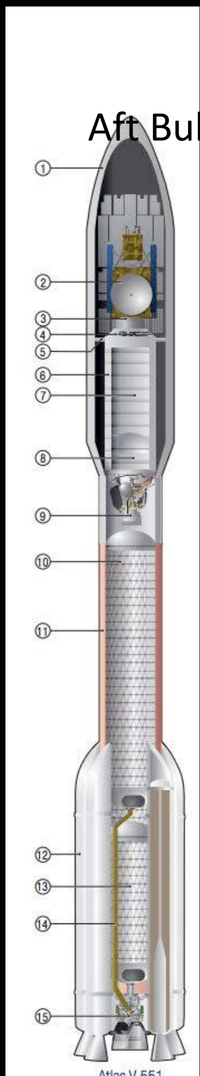


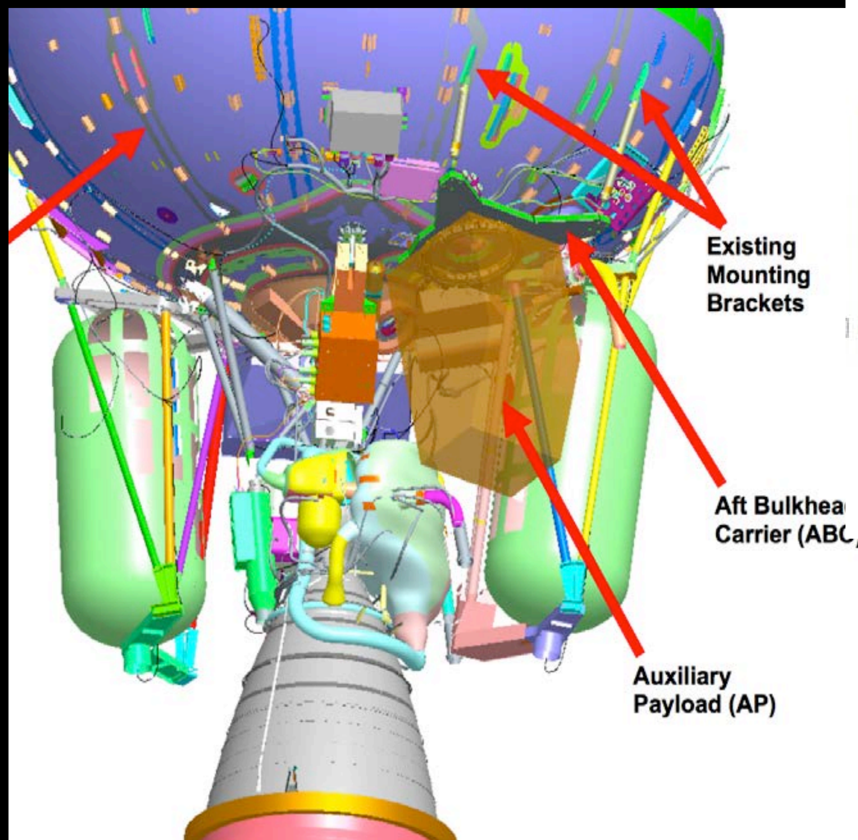


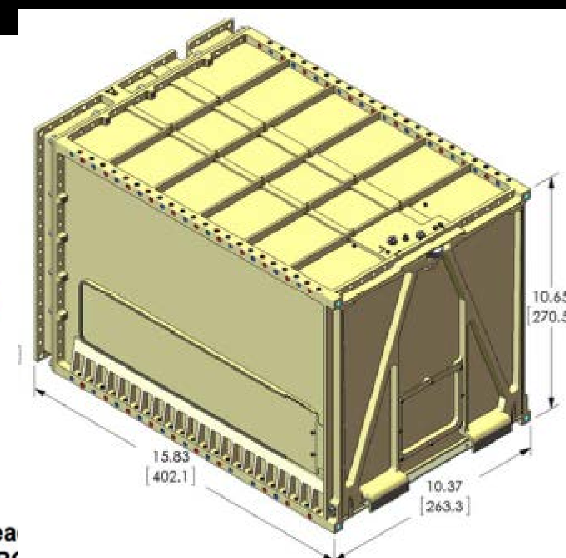


Launch Accommodation

Aft Bul







Propulsion System Options

For our desired mission, we needed a high ΔV (MOI), a relatively high Specific Impulse, sufficient thrust to keep the MOI burn relatively short, all within a relatively small package (12U). We concluded a biprop was our only way to meet these criteria. The system fills a trade space of 1-10 kg payload mass, 6-27U volume & mass, and 1000 to 3000 m/s ΔV, within the ABC constraints