N.O.M.A.D

Novel Orbital Mission for Asteroid Determination

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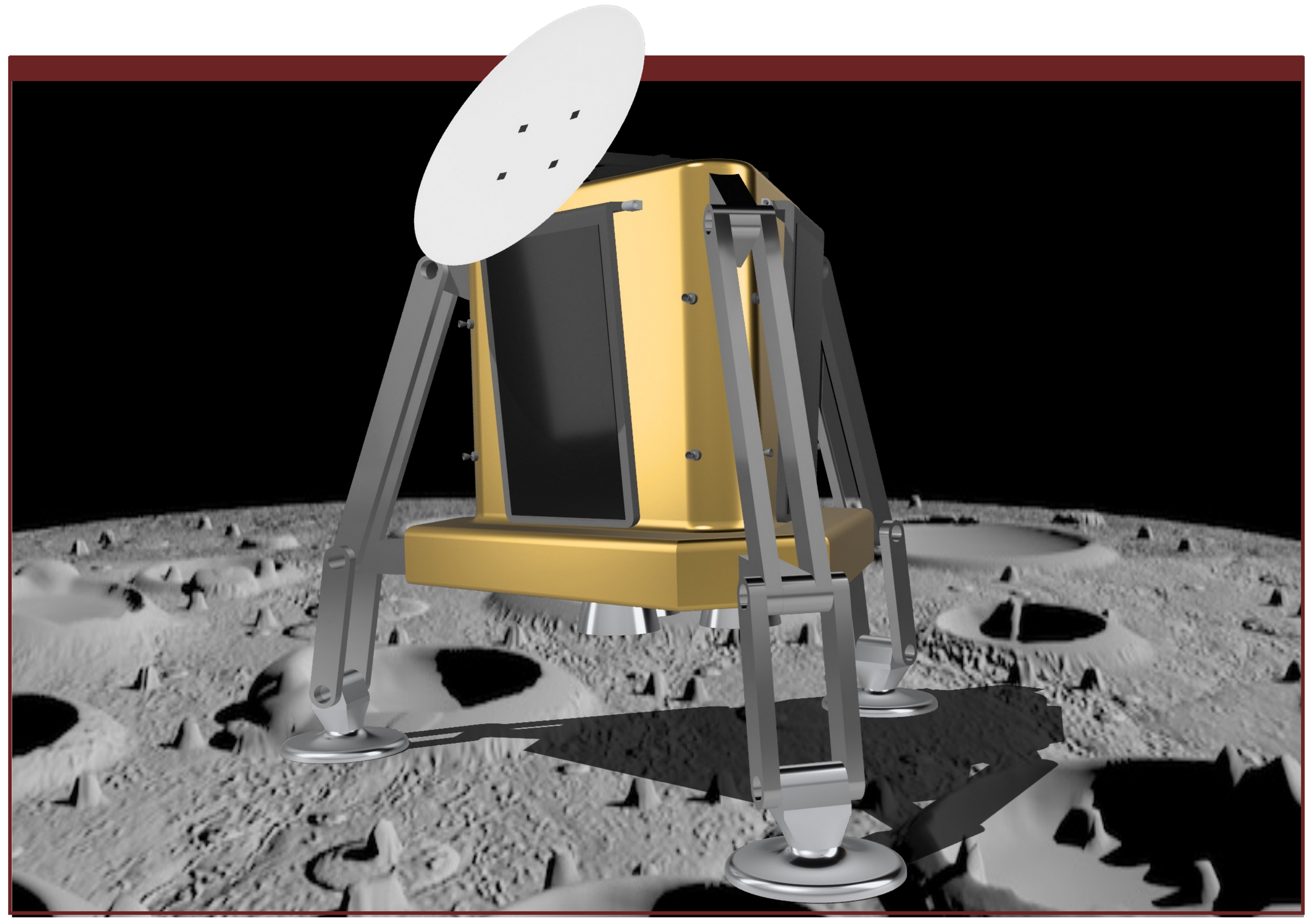
Mission Purpose

N.O.M.A.D will consist of a one-way probe with autonomous landing and composition analysis of the asteroid 16-Psyche.

This asteroid is of interest as it is disputed among planetary scientists to be an ancient planetary core. Further investigation of this asteroid has not been pursued despite the potential for knowledge on planetary formation in on solar system.

Upon landing the probe will extract samples and analyze the composition as well as photograph the surface and transmit the data back to Earth where it will be extensively studied by planetary scientists.



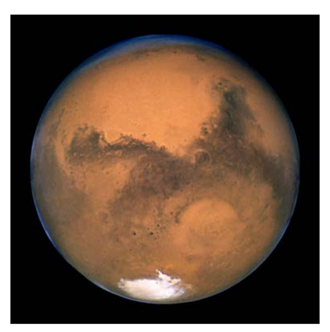
Mission Objectives

1) Arrive to Psyche Safely
2) Using a gravity assist from Mars.
3) Approximately 3.5 years away from Earth.
4) Orbit around Psyche before landing.
5) During orbit, photographs will be captured of the asteroid.
6) **Land on Psyche and collect samples.**
7) Analyze samples and data

Mission Configuration

Launch

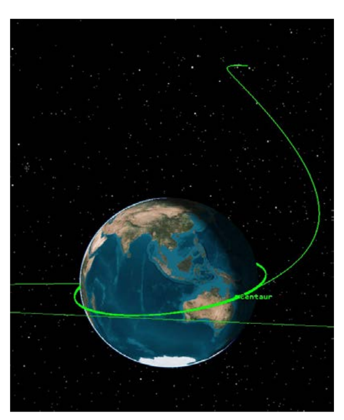
Parking Orbit



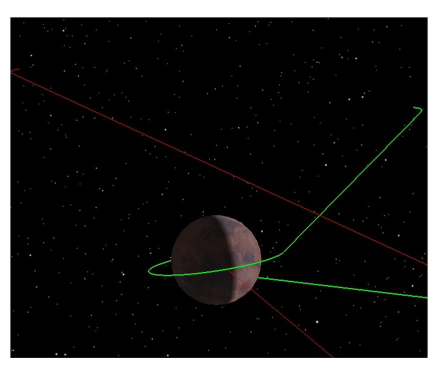
Mars Fly-by

Arrival & Landing

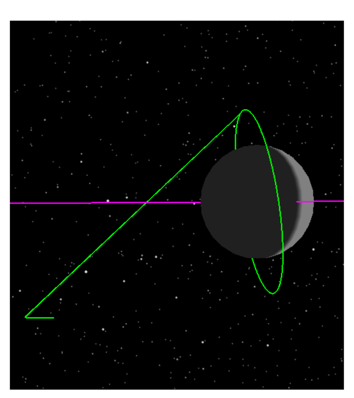
Spaceflight Trajectory



Earth Parking Orbit and transfer orbit to Mars



Mars fly-by Including Blackout communication on Dark side of planet



Arrival into orbit at Psyche

Mission Timeline

Design and Development (2023)
Project design and development stages begin.

Manufacturing (2025)
Construction and assembly of the spacecraft and its instrumentation begins.

Launch (Dec. 2026)
Construction of payload is complete and is ready to be launched.

Transit (2026-2028)
Twenty-three-month long journey to Psyche begins which includes a mars flyby.

Orbital Scan & Landing (2028)
Orbit around 16 Psyche and land on the surface.

Data Collection and Transmission (2028-2029)
Lander will start collecting samples to analysis and transmit back to earth. Expected two-week mission duration

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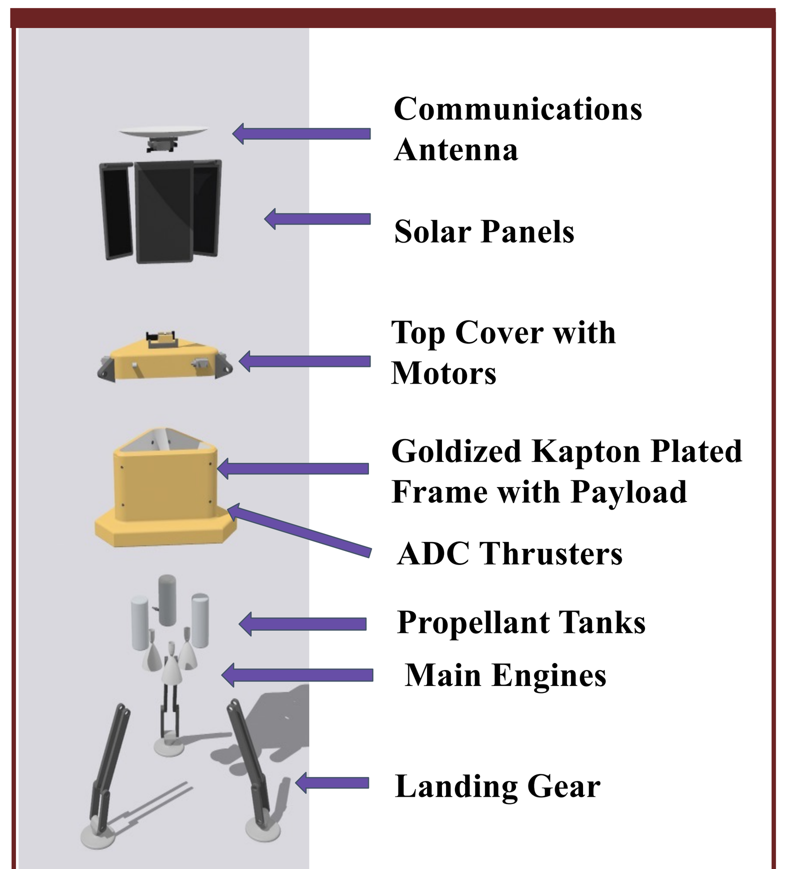
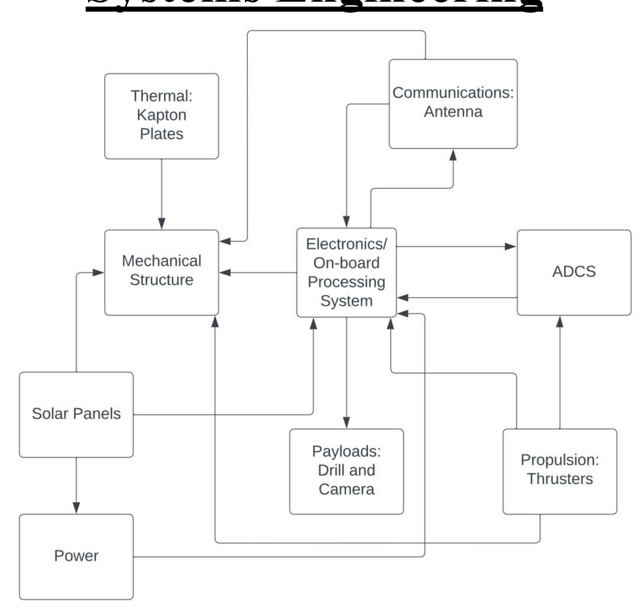
Systems Overview



Systems Engineering



Thermal Systems

Simulation from 7 km Orbit at 16-Psyche:

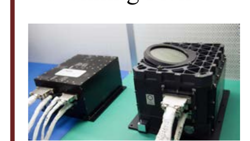
Passive System	Eclipse Case (ºC)	Hottest Case (ºC)
Polished Beryllium	97.54	168.8
Goldized Kapton	-0.93	50.45
Gold	-42.42	-0.05

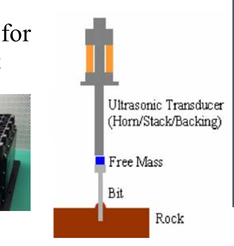
Maintain between 0°C and 125 °C

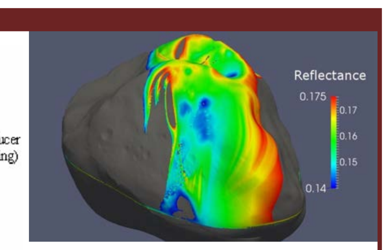
Selection: Goldized Kapton

Payload

Laser Altimeter for Scanning Planet







The spectrometer subsystem will enable scientists to understand the geochemical composition of Psyche, much like the asteroid 21 Lutetia above.. Through examination of the cored samples scientists can understand more about other asteroids, our earth, and our solar system! A Nickel-Iron rich asteroid could mean this was once a young planet.

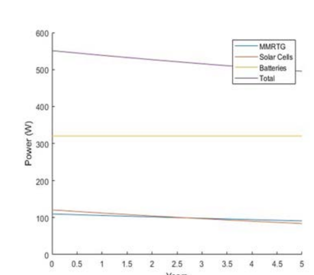
Onboard Data Handling

BAE Sytems RAD750
- 200 Mhz w/ 266 MIPS
- Operations at 100 Hz, giving us 2M clock cycles available per frame
- Rad-hardened up to 300 krad
  - Avg of ~6000 years before a radiation fault.

VxWorks
- VxWorks has a long history, and a dense flight record, with recent uses on the Perseverance and Curiosity rovers, along with the James Webb Space Telescope

Power Systems

Power System shall provide a minimum of 433 W to the spacecraft for the duration of the mission



Component	Max Power (W)
Drill	55
Onboard Camera	4.5
Laser Induced Spectrometer	29.5
X-ray Spectrometer	2
Propulsion system	135
Landing Guidance System	177
ADCS	30
Total Required	**433.0**

Source	Power (W)
Optimus Battery 8x	320
MMRTG	110
Solar Panels	130
Total Available	**560**

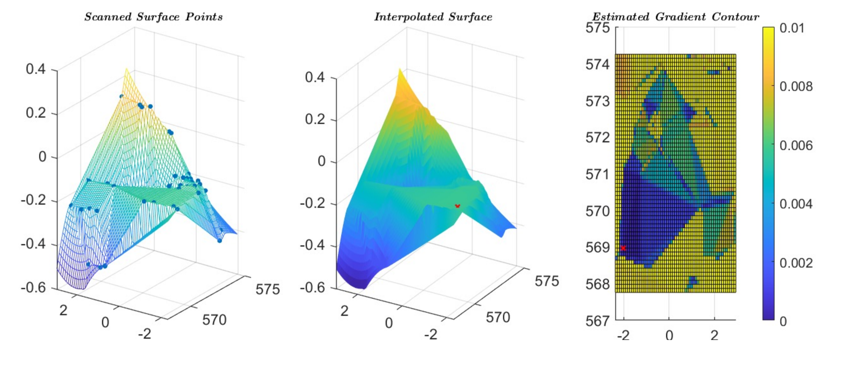
Acknowledgements

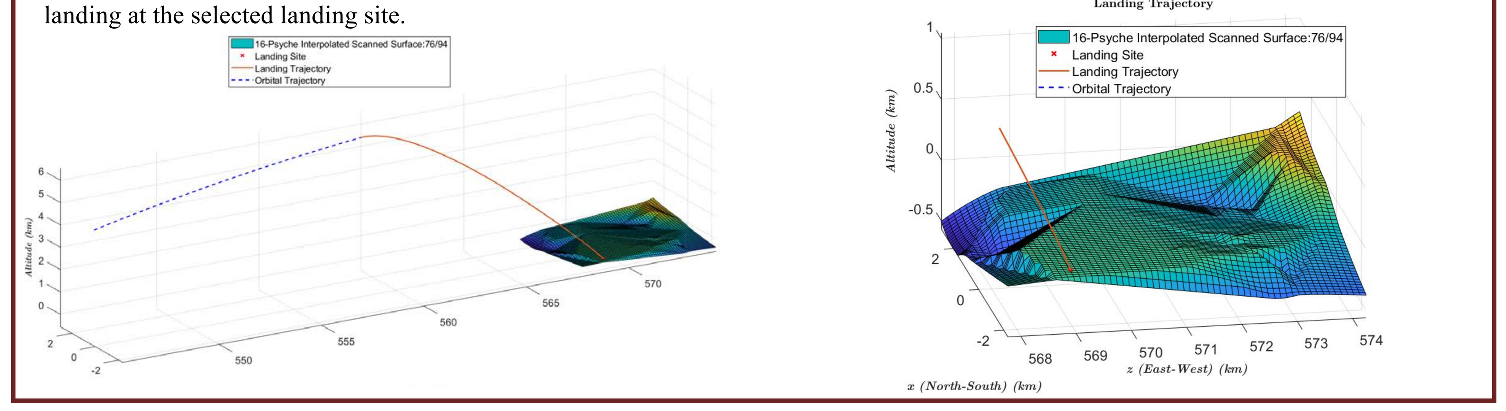
Special thanks to our advisor Dr. Ahmad Bani Younes, SDSU Aerospace Department, and SPACE Lab for their guidance and resources throughout the design of this mission

Autonomous Systems

Onboard Laser Altimeter Scans the surface geometry of the planet repeatedly throughout orbits. Surface gradient is calculated and logged autonomously. NOMAD chooses best suitable landing site based on the flattest point and selects that landing site to autonomously land at.

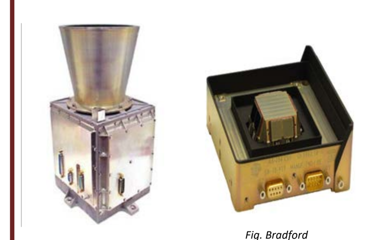
Fractional Polynomial guidance is then used for landing where the ADCS System controls the commanded pitch and yaw maneuvers and stops roll. This in combination with the main engines will allow for a propellant efficient and precise landing at the selected landing site.

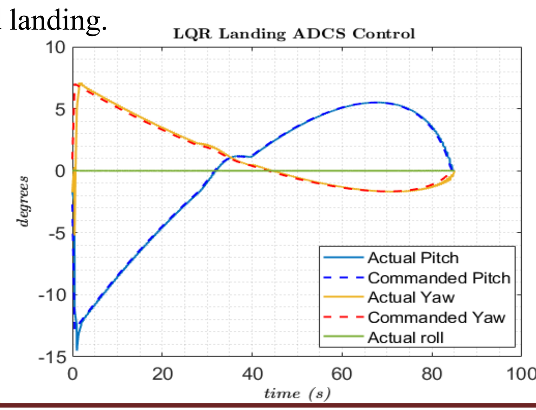


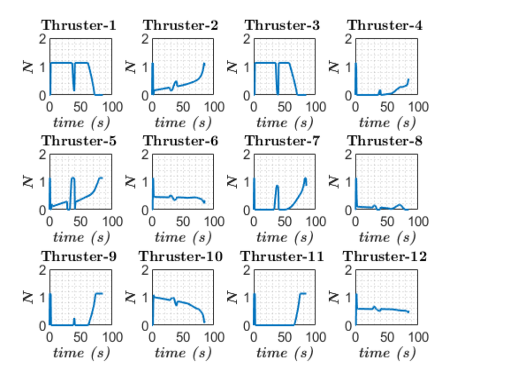


ADCS Systems

The attitude determination and control subsystem will perform execute maneuvers determined by the landing guidance system. The system needs to converge within 10 seconds with an accuracy of within 5° of the desired attitude. This system will use multiple sensors to determine the attitude of the lander using an IMU, a coarse sun sensor, and star tracker. An LQR controller is utilized to determine the thrust needed in each axis for the lander to achieve the correct orientation. The correct orientation is achieved using the 12 Aerojet Rocketdyne attitude thrusters. All 12 work in tandem to make the correct attitude maneuvers to keep the lander stable throughout its descent and landing.



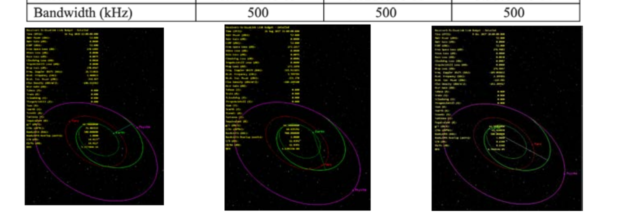




Communication Systems

Requirements:
For antennas, we will be using the Deep Space Network including Goldstone, Madrid and Canberra. We will need an input of power no less than 52 dBW. We will need the following hardware: S-Band Transponder, mixer, filters, amplifiers, and antennas. We believe a high-gain parabolic reflector dish works best for our mission profile and objectives. Using a dish diameter of ~2m would meet our goal of 500 kbps in the S band for the orbiter's connection to Earth. A 30 cm dish on the lander would still achieve an 18.4 dB gain and be able to communicate with the orbiter 7 km up. Will need to use S-band as the received frequency will be over 4 GHz. The ideal data rate we want is greater than 0.5 megabits per second and no less than 4 megabits per second.

	Worst Case	Average Case	Best Case
Transmitter Output Power (per carrier) (dBW)	52	52	52
EIRP (dBW)	52	52	52
Space loss (dB)	276.4802	273.2657	270.6884
Rain Loss (dB)	0.0038	0.0035	0.0074
Clouds/Fog Loss (dB)	0.0007	0.0006	0.0010
Prop Loss (dB)	276.4847	273.2698	270.6967
Freq Doppler Shift (kHz)	-104.098832	-215.912655	21.553026
Received Frequency (GHz)	3.399896	3.399784	3.400022
Received Iso. Power (dBW)	-224.485	-221.270	-218.697
Flux Density (dBW/m^2)	-192.399417	-189.184580	-186.697
g/T (dB/K)	61.5	61.5	61.5
C/N_0 (dB*Hz)	65.614458	68.829296	65.614458
C/N(dB)	8.6248	11.8396	14.4127
E_b/N_0 (dB)	8.6248	11.8396	14.4127
BER	6.746814e-05	1.628133e-08	5.317344e-14
Bandwidth (kHz)	500	500	500



Propulsions Systems

Requirements:
Propulsive system shall hold 2.5x estimated propellant consumption of 100 kg

Propulsive system shall produce a thrust range from 2400-12000N necessary for Landing

Propulsive system shall include attitude thrusters for a 10 deg/s Attitude maneuver

Design:
3 Aerojet Rocketdyne R-40B Bipropellant

Design Characteristics
- Propellant .... MMH/NTO(MON-3)
- Thrust/Steady State* .... 4,000 N (900 lbf)
- Inlet Pressure Range .... 27.6 – 10.3 bar (400 - 150 psia)
- Chamber Pressure* .... 10.34 bar (150 psia)
- Expansion Ratio 60:1
- Flowrate* .... 1,400 g/sec (3.07 lbm/sec)
- Valve .... Aerojet Rocketdyne Single Seat
- Valve Power .... 70 Watts @ 28 Vdc

Performance
- Specific Impulse* .... 293 sec (lbf-sec/lbm)
- Total Impulse .... 92,073,600 N-sec (20,700,000 lbf-sec)
- Total Pulses 50,000
- Minimum Impulse Bit .... 111 N-sec (25.0 lbf-sec)
- Steady State Firing Cumulative .... 23,000 sec

12 Aerojet Rocketdyne MR-103-J Attitude Thrusters

Design Characteristics
- Propellant .... Hydrazine
- Catalyst S-405
- Thrust/Steady State .... 1.13 - 0.19 N (0.253 - 0.043 lbf)
- Feed Pressure .... 28.3 - 4.8 bar (420 - 70 psia)
- Chamber Pressure .... 23.8 - 4.5 bar (345 - 65 psia)
- Expansion Ratio 100:1
- Flow Rate .... 0.5 - 0.09 g/sec (0.0011 - 0.0002 lbm/sec)
- Valve .... Dual Seat

Performance
- Specific Impulse .... 224 - 202 sec (lbf-sec/lbm)
- Total Impulse .... 183,000 N-sec (41,000 lbf-sec)
- Total Pulses 1,002,345
- Min Impulse Bit .... 0.0133 N-sec @ 6.9 bar & 15 ms ON .... (0.003 lbf-sec @ 100 psia & 15 ms ON)
- Steady State Firing .... 3,600 sec Single Firing .... 84hrs Cumulative

250 Kg of propellant needed for landing + extra 150kg for extreme divert landing scenario

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