Icarus

2018 Red Eagle International Design Competition

Cerritos High School | California State University, Long Beach

Mission Objective

To design a lander capable of carrying a 10 metric ton payload (and crew) to the surface of Mars built and launched by 2026, to provide crucial information for exploration/development on Mars, to recapture the interest of the public for space exploration/research.

System Overview

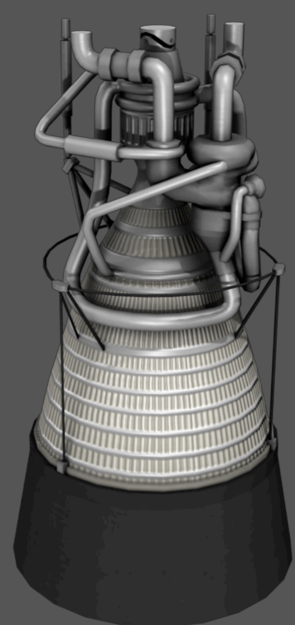
- Primary Systems
  - Lander, Fuel, Engines, Payload
- Sub-systems
  - Power Systems, Navigation Computer, Communications, Reaction Control System
- Protection
  - Heating, Micrometeorite, Radiation

Primary Systems

The Icarus

- 85 ft (25.9 m) tall
- 29.52 ft (9 m) diameter
- Payload Bay Volume: 413 m^3

Engine Considerations

Vikas-4B	RL10B-2	Merlin 1D	Raptor
			

Engine Considerations (cont.)

Engine	Vikas 4B	RL10B-2	Merlin 1D	Raptor
Fuel	UH25	Liquid Hydrogen	RP-1	Liquid Methane
Oxidizer	N2O4	LOX	LOX	LOX
Specific Impulse/ISP (sec)	296.2	465.5	275	334

Propellent Types

UH25 + N_2O_4	LH_2 +LOX	RP-1+ LOX	Liquid Methane +LOX
Fuels stable at room temperature Hypergolic Deadly if inhaled or ingested	Highly efficient engine Propellants must remain liquid: H_2: -259°C to -252°C O_2: -218°C to -182°C	Oxidizer "super-chilled": O_2: -340°C (Increases fuel efficiency) Propellent degrades over time	Engine not tested yet

Engine Considerations (cont.)

Engine	Vik-4B	RL10B-2	Merlin 1D	Raptor
Mass (kg)	900	301	470	N/A
Thrust (N)	805,000	110,000	934,000	3,050,000 (predicted)
Thrust-to-mass Ratio	894	365	1990	N/A

Engine Comparisons (cont.)

Engine	Vikas-4B	RL10B-2	Merlin 1D	Raptor
# of Engines	Min: 1 Optimal: 3	Min: 2 Optimal: 4	Min: 1 Optimal: 3	N/A

Engine Configuration

- 3 Vikas 4B Vacuum Engines
  - Triangular pattern
  - All engines capable of gimbaling

Sub-Systems

Terrain-Relative Navigation

1. Will use system comparable to Mars 2020 Rover
2. Will use onboard Synthetic-aperture radar to map ground
3. Will use an array of sensors to get variables such as velocity, drag, temperature, and attitude.
4. Will then use these variables to calculate alternative routes the lander could take
5. Would then divert course if necessary

Communication

- Will utilize a HRT440 X-Band High Rate transmitter
- Is able to transmit a minimum of 25 KBPS of data at a frequency of 8200.5 MHz
- Three antennas would be present
- Would use MRO as relay to Earth

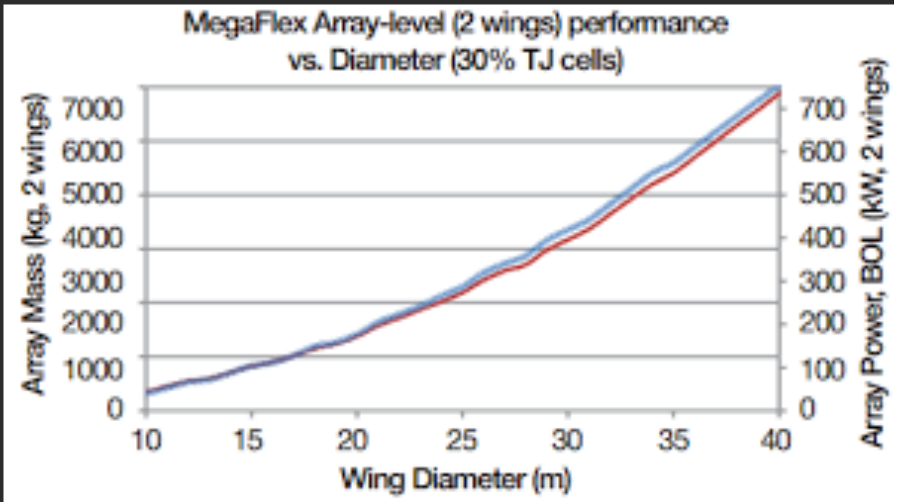
HF Band	3 to 30 MHz
VHF Band	30 to 300 MHz
UHF Band	300 to 1000 MHz
L Band	1 to 2 GHz
S Band	2 to 4 GHz
C Band	4 to 8 GHz
X Band	8 to 12 GHz
Ku Band	12 to 18 GHz
K Band	12 to 27 GHz
Ka Band	27 to 40 GHz

Reaction Control System

- 18 R-4D thrusters in the same configuration as the Dragon Capsule
- Fuel flow rate: 0.0531 Kg/sec
- 35 Kg fuel stored in four Tanks
- Dry mass of 97.5 Kg

Power

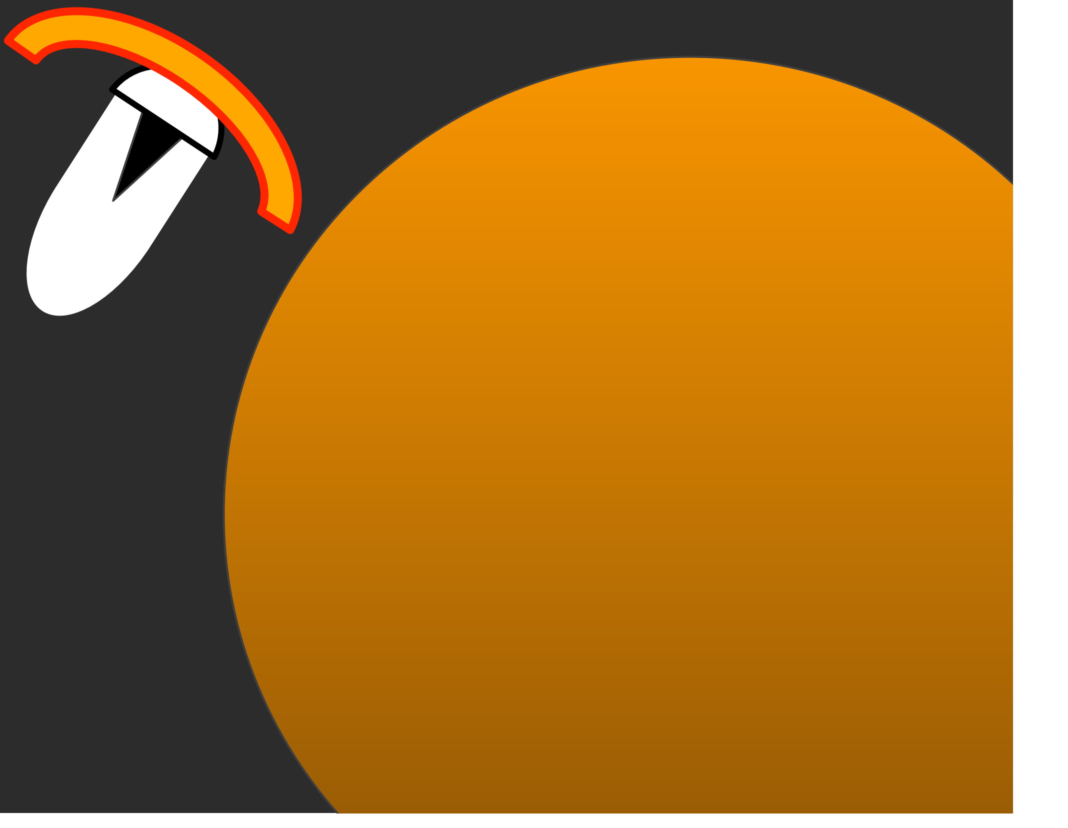
- 5 Lithium Sulfur batteries providing a total of 125 Kwh storage capacity
- 2 Megaflex solar arrays each with a diameter of 5.5 m
- Will provide approximately 25 Kw of power at Martian SOI



Power Breakdown

Function	Notes	Amount
Communication Systems	Radio receivers and transmitters	40 Watts
Life Support Systems	Thermal protection, lighting, hygiene, etc	17 Kilowatts
Spacecraft Control Systems	RCS thrusters, sensors	2 Kilowatts
TRN Equipment	SAR cameras, sensors	1.5 Kilowatts
Misc	Onboard computer systems	1.6 Kilowatts

Protection



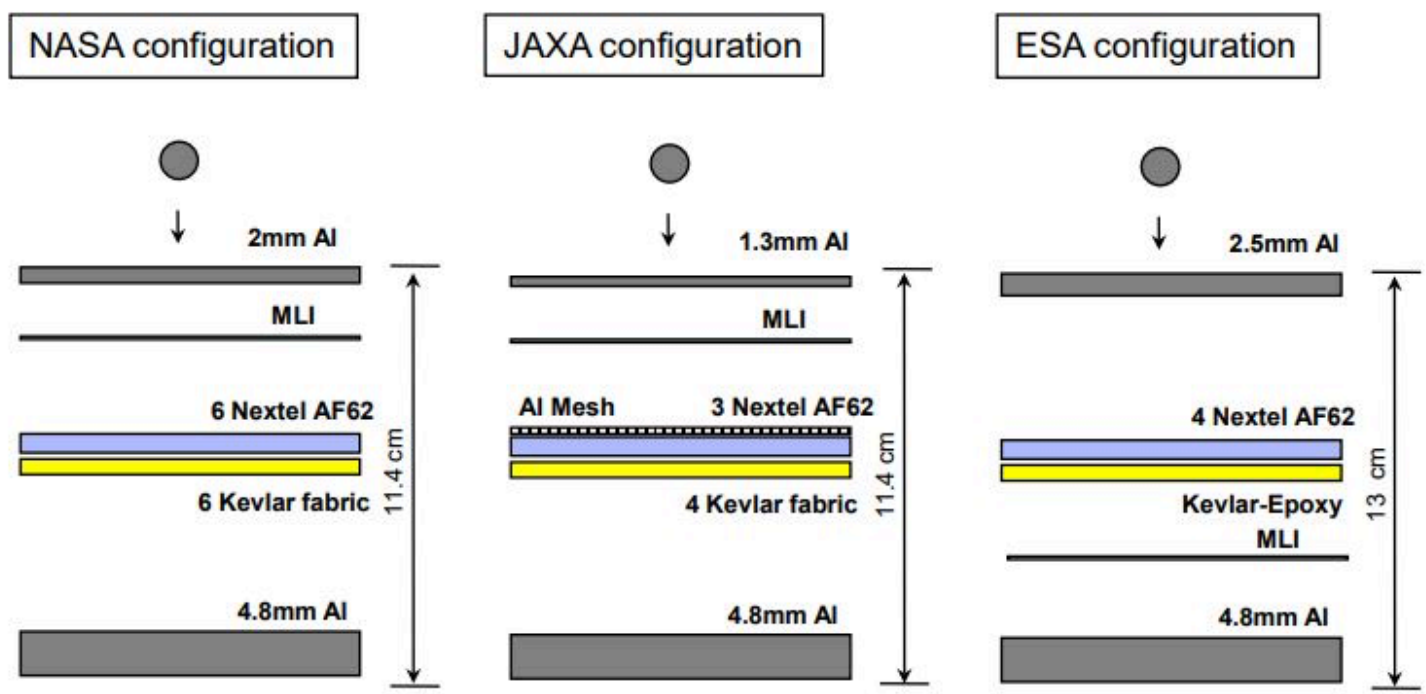
Heat Shield

- The craft will have PICA (Phenolic Impregnated Carbon Ablator)-X Heat Tiles
  - Produced by SpaceX
  - Can experience temperature of up to 1,600 degrees C

Heat Protection

- Space Shuttle’s Heat Blankets
    - Lined inside craft
    - Absorbs heat
- Can endure 3000°F (1650°C)

Micrometeorite Protection



Typically, bumpers are Al 6061-T6, rear walls are Al 2219-T87 or Al 2219-T851
Kevlar 29 style 710 or Kevlar KM2 style 705 fabric are typically used

Radiation Protection

- 4 cm of water around payload bay (28.5% decrease in radiation exposure)
- Reduces radiation exposure to 180 mSv for 6 month trip.
- Craft will rotate to facilitate temperature control

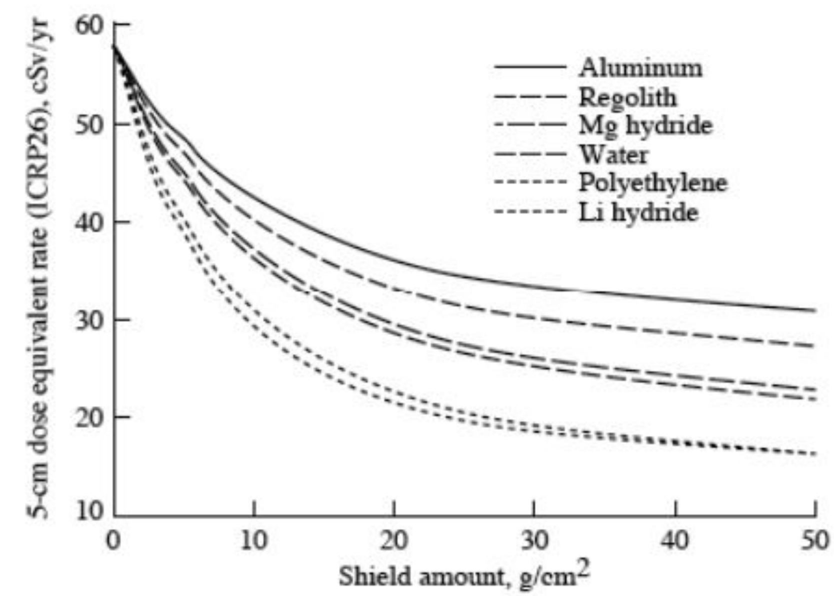


Figure 1. Point estimates of 5-cm depth dose for GCR at Solar Minimum as a function of areal density for various materials (figure1.jpg). (Simonsen et al. 1997)

Mass Breakdown

Primary

Sub-Systems

Protection

Mass Breakdown (Primary Systems)

Item	Notes	Mass
Lander	Aluminum-Lithium Alloy	11,680 kg
Fuel	UH-25 and N_2O_4	76,000 kg
Rocket Engines	3 Vacuum Vikas-4B Engines	2,700 kg
Payload	10 metric ton payload	10,000 kg

Total: 100,000 kg

Mass Breakdown (Sub-systems)

Item	Notes	Mass
Power	Solar arrays and batteries	450 kg
Terrain Navigation System	Multiple radar cameras and systems	200 kg
Communication Systems	Multiple antenna and systems	130 kg
Reaction Control System	18 R-4D Thrusters	130 kg

Total: **910 kg**

Mass Breakdown (Protection)

Item	Notes	Mass
Radiation protection	Water	9,700 kg
Heat Shielding	Heat blankets and PICA-X tiles	3,000 kg
Micrometeorite Protection	2 Aluminium Plates, Kevlar, Nextel, and MLI	110 kg

Total: 12,800 kg

Total Mass Breakdown

System	Mass
Primary Systems	100,380 kg
Sub-Systems	910 kg
Protection Systems	12,810 kg

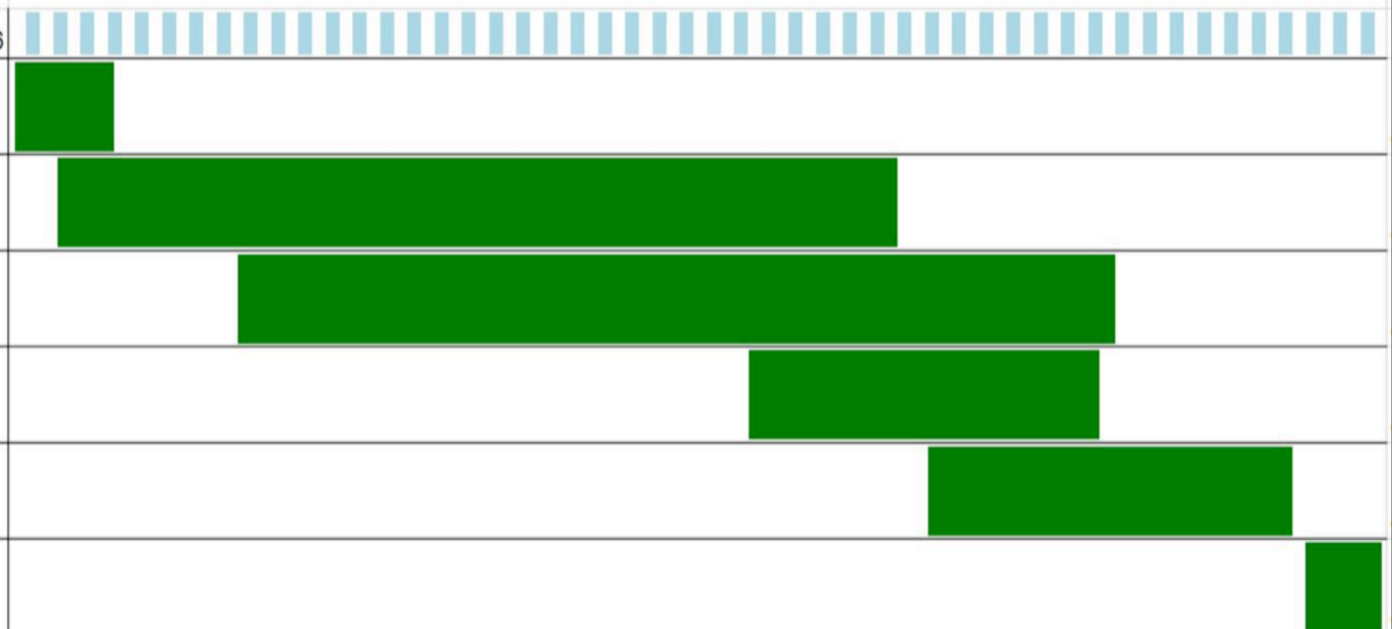
Total: 114,000 kg

Build Schedule

Schedule

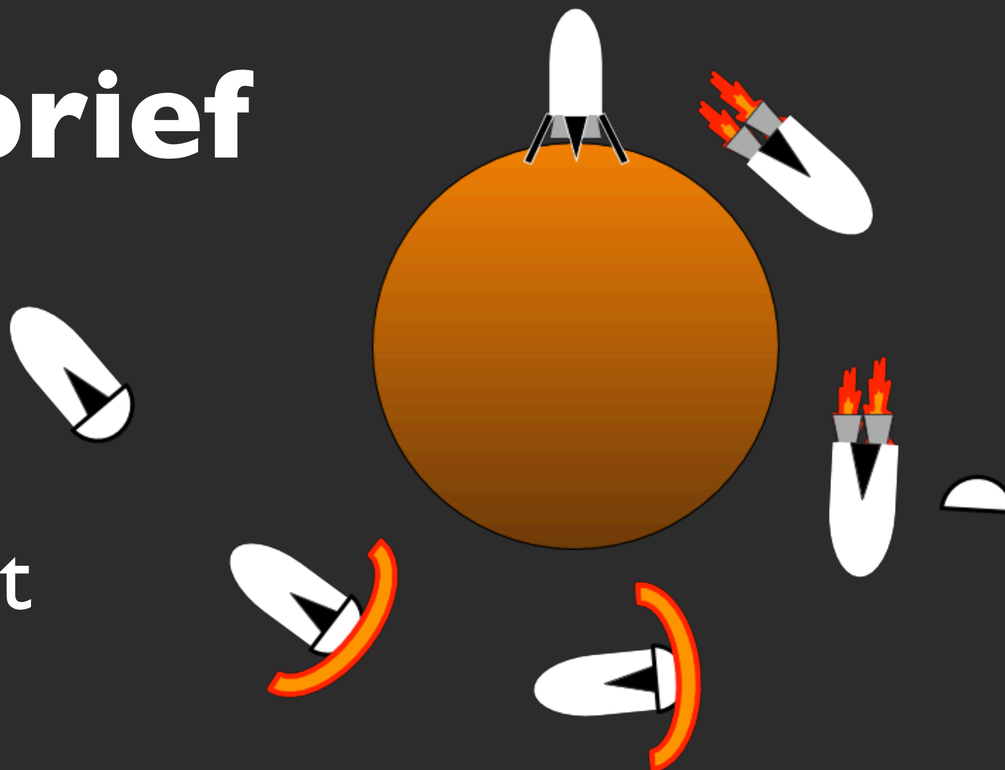
	Start Date	End Date
Icarus	Aug 26, 2018	Dec 31, 2026
Planning and Design	Sep 1, 2018	Apr 9, 2019
Tech Development	Dec 5, 2018	Jan 17, 2024
Tech Testing	Jan 10, 2020	May 16, 2025
Spacecraft Production	Feb 21, 2023	Apr 10, 2025
Spacecraft Testing	Mar 26, 2024	Jun 15, 2026
Final Preparations	Jul 15, 2026	Dec 30, 2026

Timeline (each rectangle is one month)



Mission Debrief

1. Aerobraking
2. Re-entry
3. Powered Descent
4. Landing

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Aerobrakin
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Why Aerobraking?

- This strategy saves us about 115,000 kg worth of fuel, decreasing our mass by 52%.
- It also has a surprisingly minimal g-load on the crew, the max deceleration they will experience will be less than 10% of one g.

ballistic coefficient

central attractive constant (m^3/s^2)

scale height (km)

$$\Delta v_1 = k\, \rho_0\, \sqrt{2\, \pi\, \mu}\, \frac{1 + e}{\sqrt{e}}\, \sqrt{H}$$

periapsis density (kg/m^3)

eccentricity of entry orbit

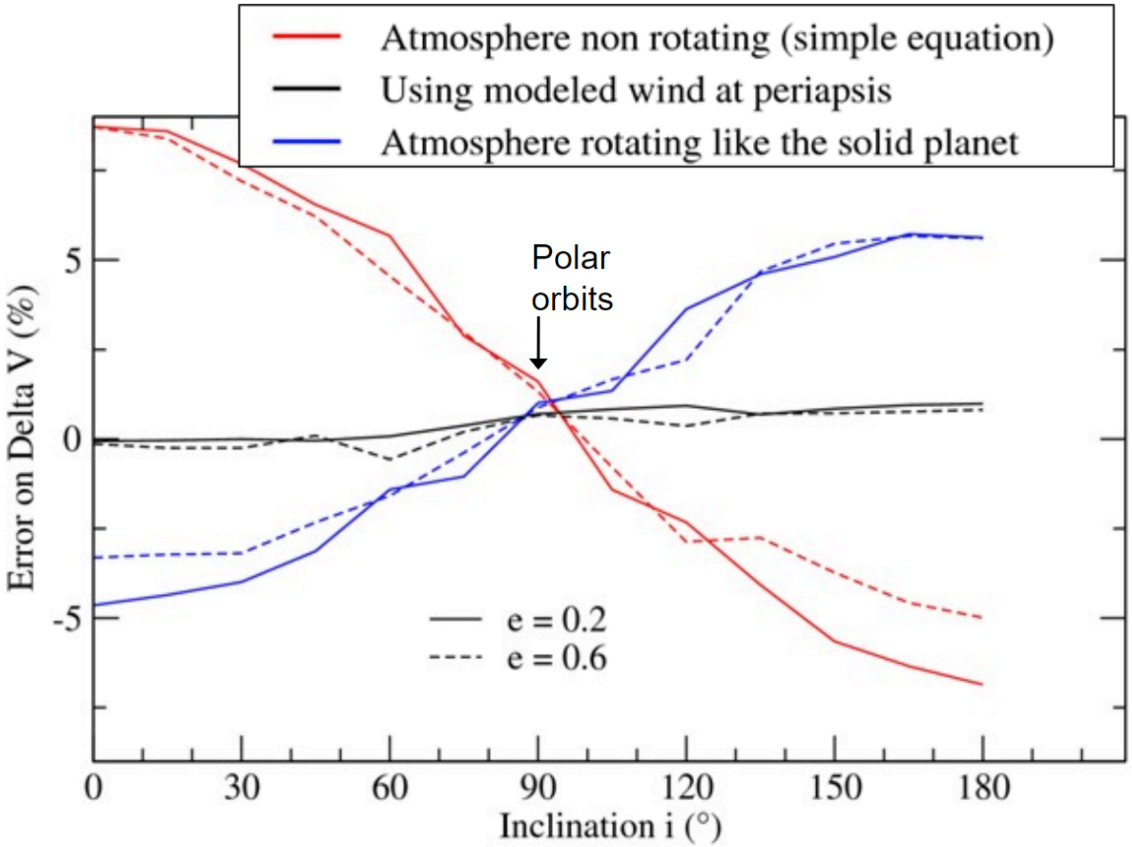
Aerobraking Numbers

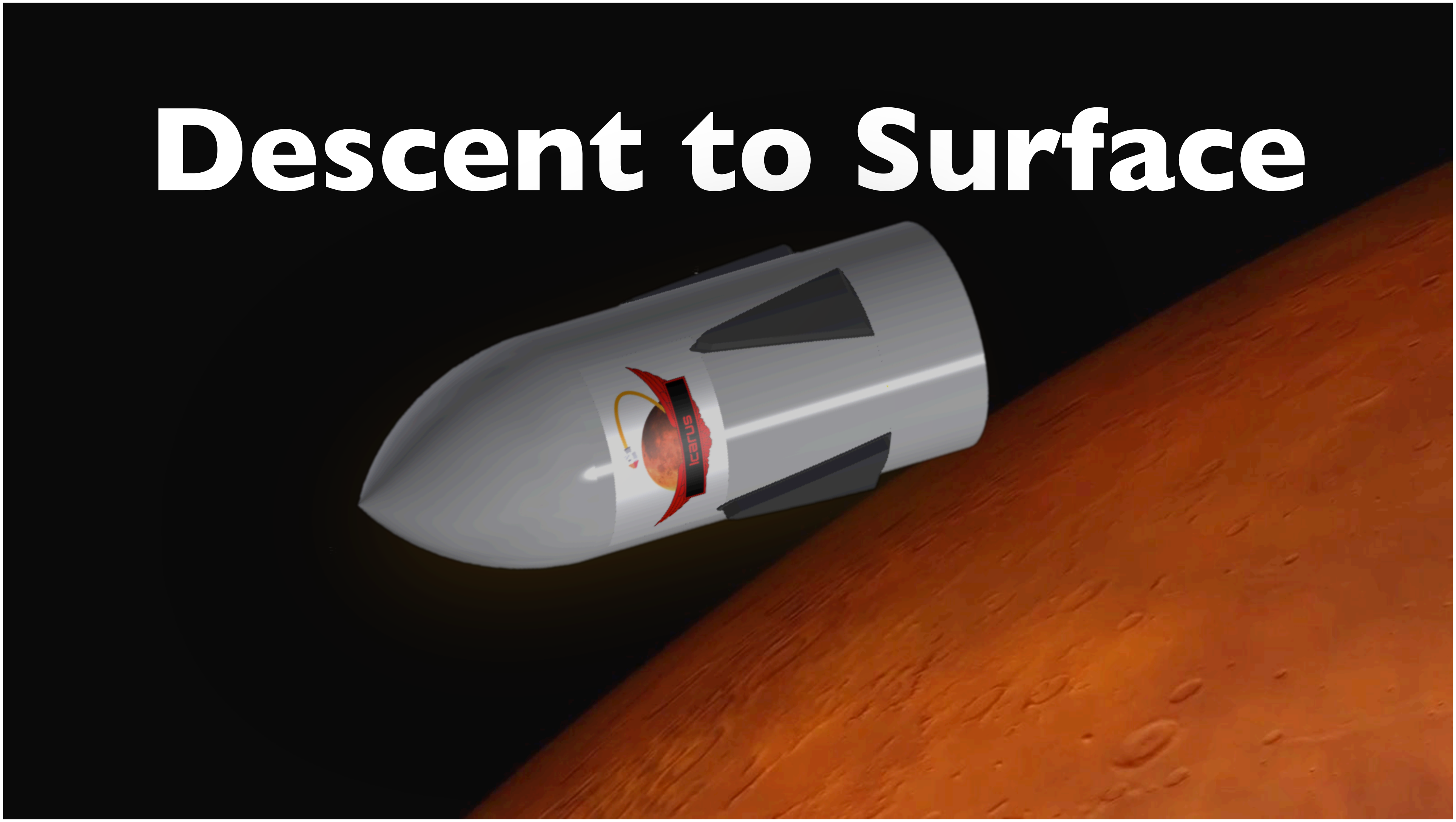
- Periapsis velocity at **98.7** km is 5.79 **km/s** while the craft is still on its hyperbolic trajectory.
- Delta v brake from aerobraking is 2.29 km/s
- This brings the craft to an orbital velocity of 3.50 km/s.
- The extra 200 m/s of delta v gives us about 9% margin for error.

Aerobraking

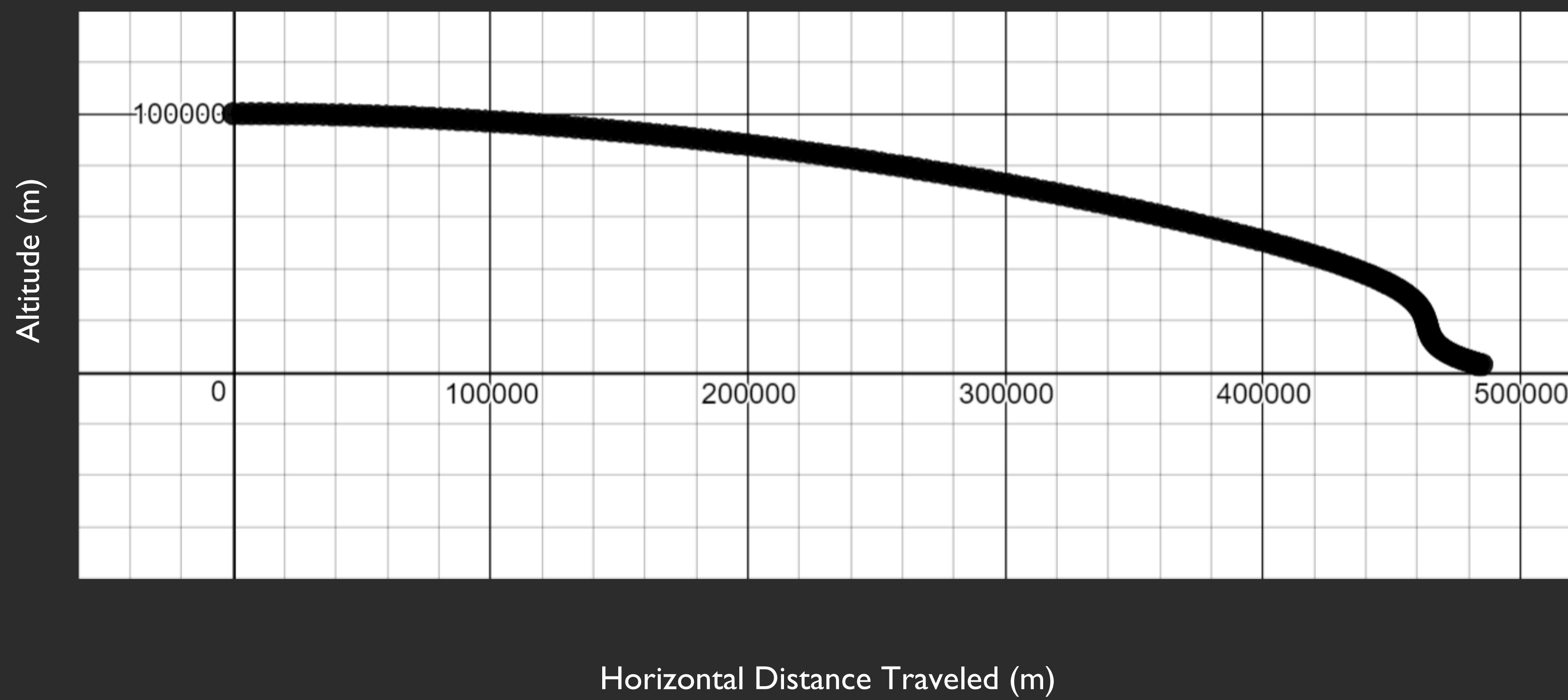
- We also chose to put the Icarus in a 90 degree (polar) orbit. This means that the delta v calculations will be the most accurate.
- Also, this way the Icarus or any future craft will be able to choose any part of Mars to land on.

The error resulting from the assumption on winds depends on the orbit inclination



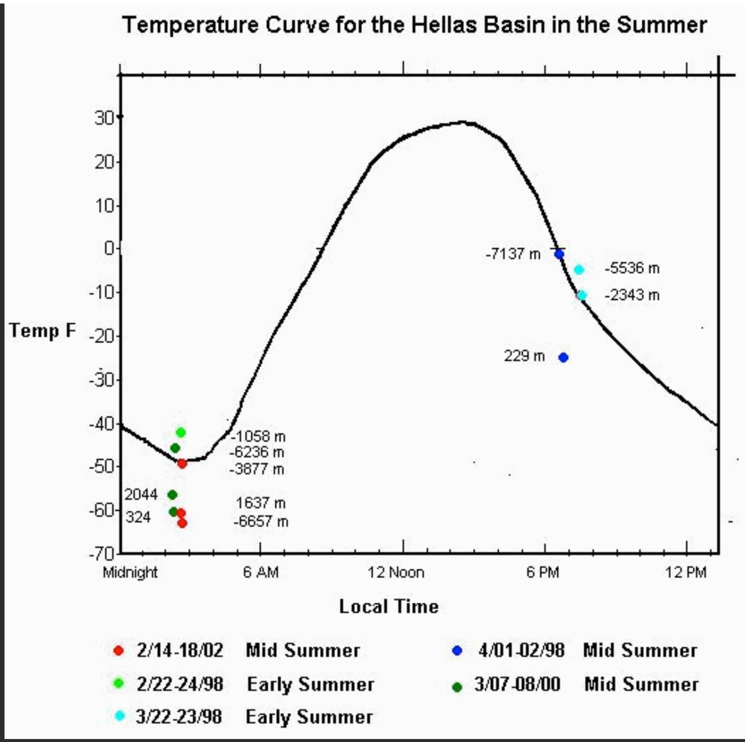

Descent to Surface
Icarus

Descent of Lander

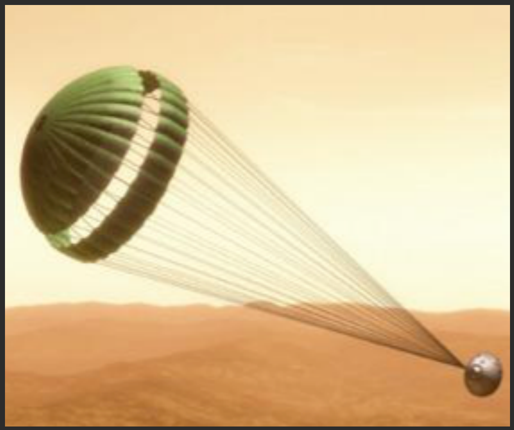


Landing Area

- Hellas Planitia
  - Has thickest atmosphere of Mars at over 10 millibars
  - Is relatively warm compared to rest of Mars
  - May have glaciers underneath surface
  - Allows lander more time to aerobrake
  - Has accessible lava tubes which may provide habitation for astronauts



Options to Descend

Parachute	Airbags	Powered Descent
		

Options to Descend (cont.)

Parachute	Airbags	Powered Descent
• Air too thin • Not enough deceleration	• Causes stress on human crew • Expensive, a lot of labor	• Optimal • Slows down in enough time

Cost Breakdown

Advanced Mission Cost Model

Lander Cost

Cost of the Lander

FY 2026: **$127,000,000,000**

$$\text{System Cost} = \alpha Q^{\beta} M^{\Xi} \delta^{S} \varepsilon^{(1/(IOC-1900))} B^{\Phi} \gamma^{D}$$

Variable:	Value Given:	Value
Q (Quantity)	Number if engineering development units, mock-ups, simulators, ground-test articles, flight test articles, and production vehicles	6
M (Mass)	Dry mass of vehicle in lbs	84,000 lb
S (Specification)	Constant for a planetary lander	2.46
IOC (Initial Operating Capability)	The system's first year of operation	2027
B (Block)	Level of design inheritance	1
D (Difficulty)	Between -2.5 to 2.5 on increments of 0.5 (-2.5 being easy and 2.5 being extremely difficult)	2.5

Cost Breakdown

Item	Cost
Lander	$127 B
Fuel	$1.3 M
Rocket Engines	$30 M

Total: $127 B

Summary

- Mass of Lander: 114,000 kg
- Many parts are proven successful
  - Several key parts are used on missions prior to launch in 2026
    - Mars 2020 for Terrain Relative Navigation
    - Polar Satellite Launch Vehicle for VIKAS-4B
- Few moving parts
  - Aerobraking
  - Powered descent
- Cost: $127 B
- Able to create working production model within 8 years

Icarus

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