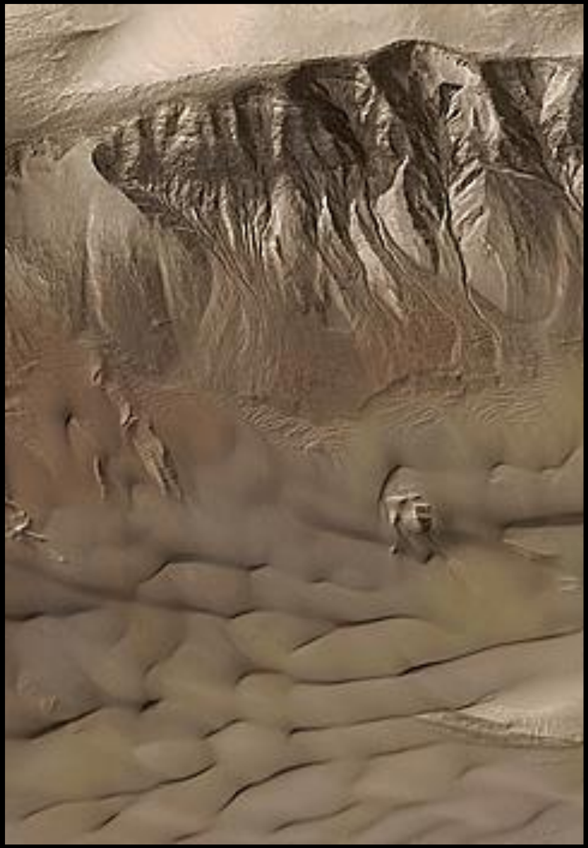
HOUGHTON ON MARS

Proposed future site of Fancher.

The next step in off-campus programs.

Houghton on Mars



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Objective: develop a detailed plan and budget for putting a professor and at least two students on Mars by 2029 using current technology.

Mission Profile

- **Minimum Crew:** 1 professor, 2 students
- **Minimum Stay on Mars:** 1 month (length of a Mayterm – does not have to be in May!)


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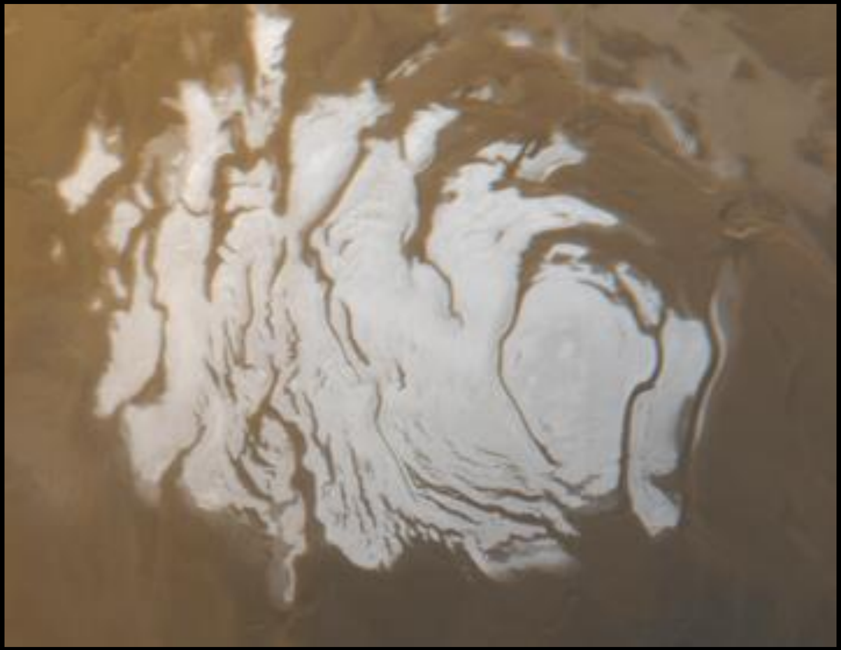
Additional Constraints:

- Minimize cost.
- Minimize length of trip.

Tradeoffs!

- Must provide food, water, and oxygen.
- Provide for return to Earth…

Mission Description



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CRITICAL:

- Overall Mission Plan
  - Number of spacecraft
  - Δv budget
- Time
  - Launch and Arrival Dates
  - In transit
  - On Mars
- Fuel / Rockets
  - Specific Impulse
  - Fuel mass

IMPORTANT:

- Space Vehicles
  - Mass
  - Size
  - Deployment
- Crew

Deliverables

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1. Powerpoint presentation:
   – Report mission specifications
   – Plots of various orbital paths
   – Any unique methods used (e.g., optimization).
2. Overview report:
   – include additional details from presentation
   – Octave code(s)

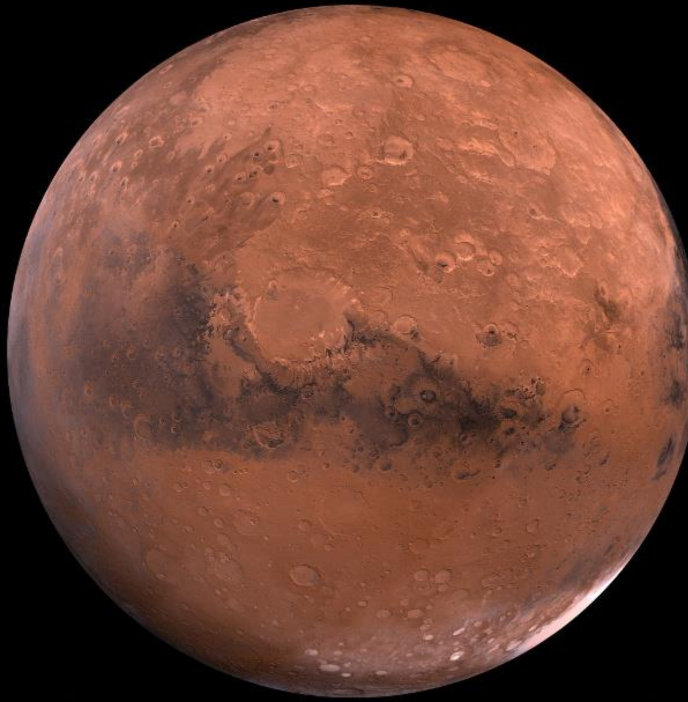
The best proposal will be selected and pursued. You are personally responsible for the safety of the astronauts.

Additional Details

- Groups of three (decide by Wed. in class)
- 8 minute presentation per person + 6 minutes for questions = 30 minutes total.
- You will decide % contribution for each member, e.g.:
  - Overall Grade: 90%
  - Contributions → Individual Grade (= Overall Grade × % contribution):
    - Tom: 70% → 63%
    - Gina: 120% → 108%
    - Joe: 110% → 99%
    - Total = 300% → 270% (Overall grade × 3)

Assumptions

- Approximate using patched conics:
  - Hyperbolic approach radius independent of departure/arrival times.
- All rocket burns are of short duration (i.e., $\ll T$)
  - If low-thrust engines are used, have to do so in a way that does not violate this assumption.
- Orbits are in the same plane (2D).
- Ignore planetary atmospheres.



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Orbital Dynamics Overview

http://nssdc.gsfc.nasa.gov/planetary/image/mera_pan08_med.jpg

- Launch spacecraft into LEO with available rockets
- Burn #1 – Escape from Earth via hyperbolic trajectory
- Transfer orbit to Mars (Hohmann or other)
- Approach Mars via hyperbolic orbit

Orbital Dynamics Overview

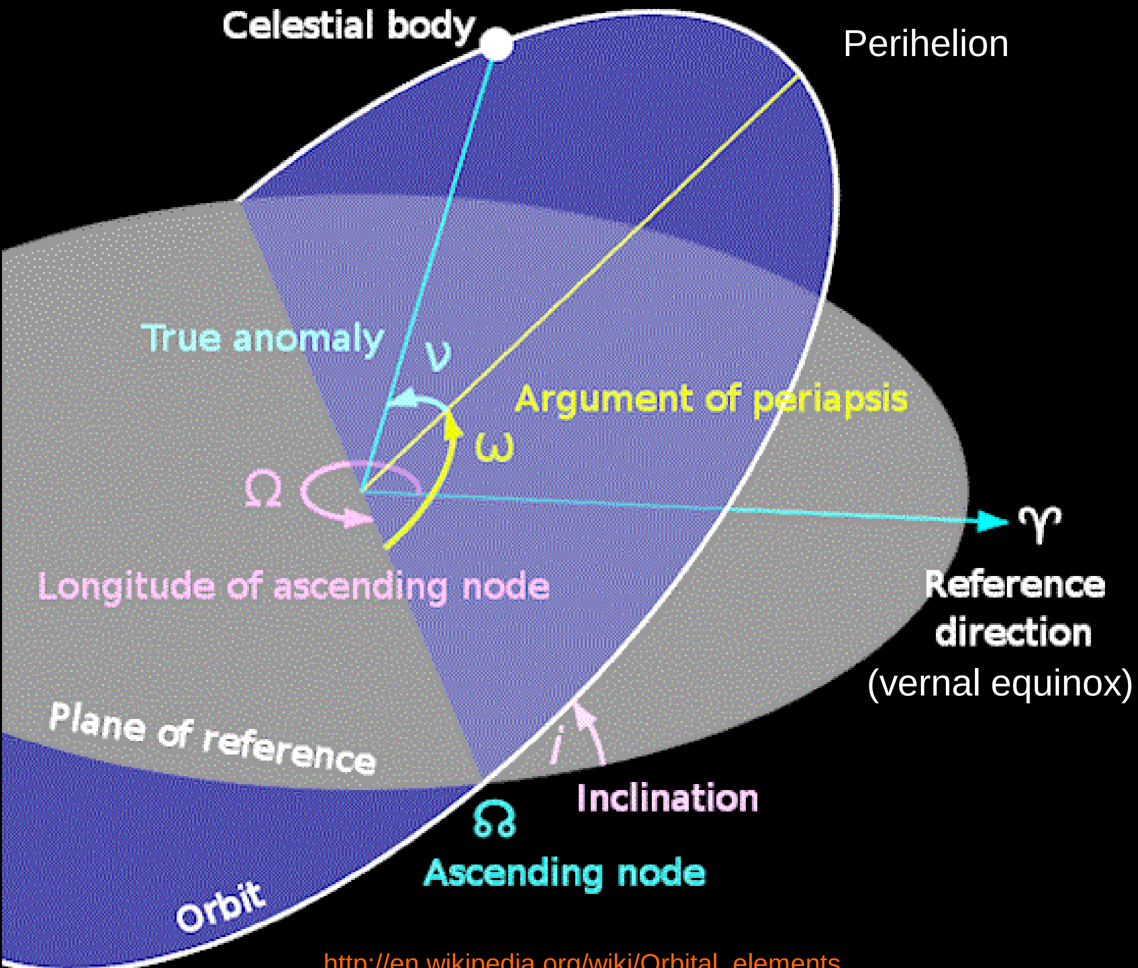
- Options for hyperbolic approach:
  1. Enter LMO:
     - Burn #2 – circularize hyperbolic approach orbit.
     - Burn #3 – transfer orbit to Mars surface (take everything to surface?)
     - Burn #4 – match speeds with Mars surface
  2. Intersect Mars surface (take everything down)
     - Burn #2 – match speeds with Mars surface
- Takeoff (rendezvous, if needed)

Reverse steps for return to Earth!

Heliocentric Planetary Orbital Elements

Planet	a (AU)	ϵ	i (deg)	ω (deg)	Ω (deg)
Earth	1.00	0.0167	~0	103	0
Mars	1.52	0.0933	1.85	286	50

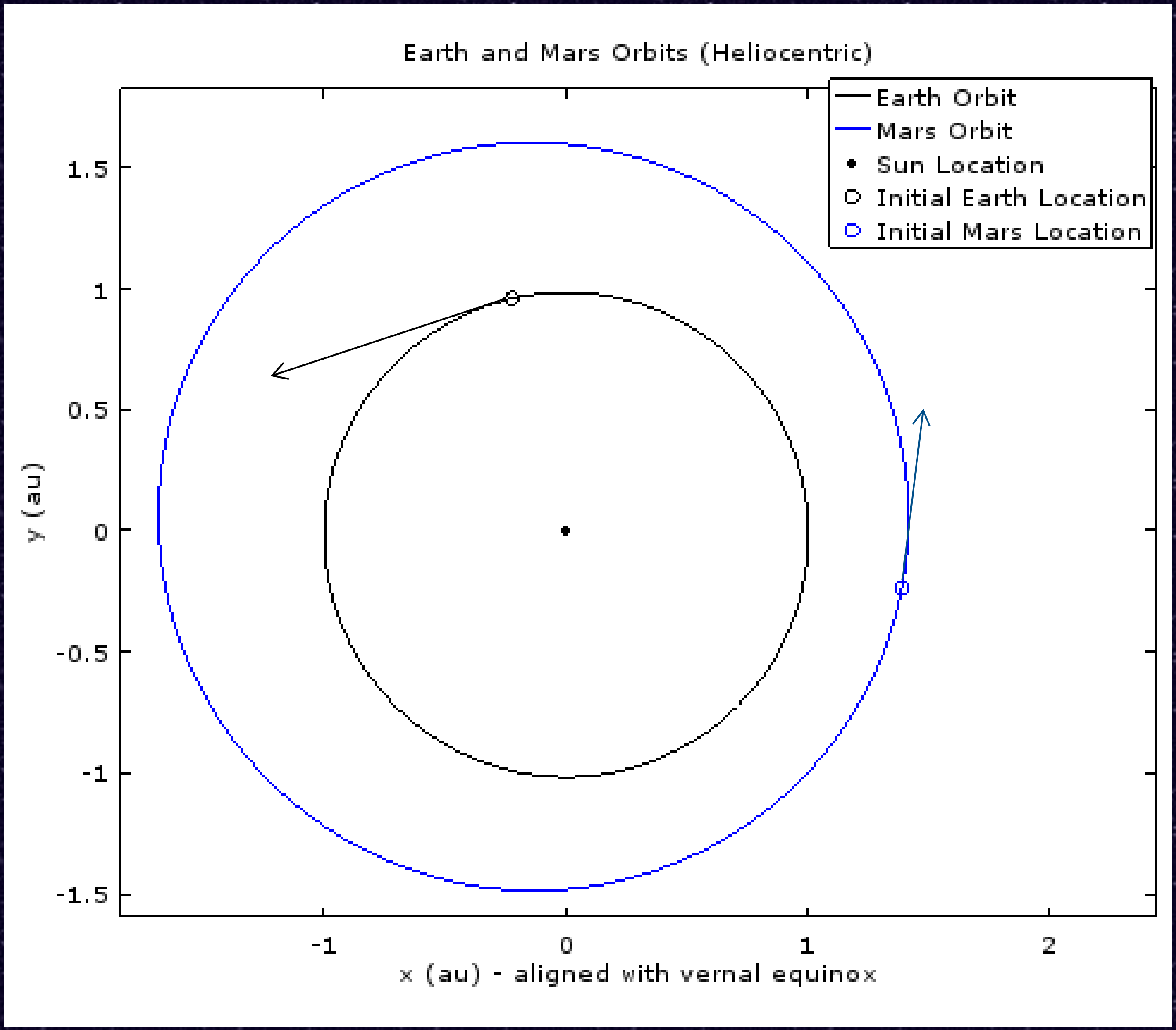
http://ssd.jpl.nasa.gov/txt/p_elem_t1.txt



a (AU)	Semi-major axis of the orbit in AU
e	Eccentricity of the orbit
i (deg)	Inclination of the orbit with respect to the ecliptic plane and the in degrees
ω (deg)	Argument of perihelion in degrees
Ω (deg)	Longitude of the ascending node in degrees

http://en.wikipedia.org/wiki/Orbital_elements

Planet Positions



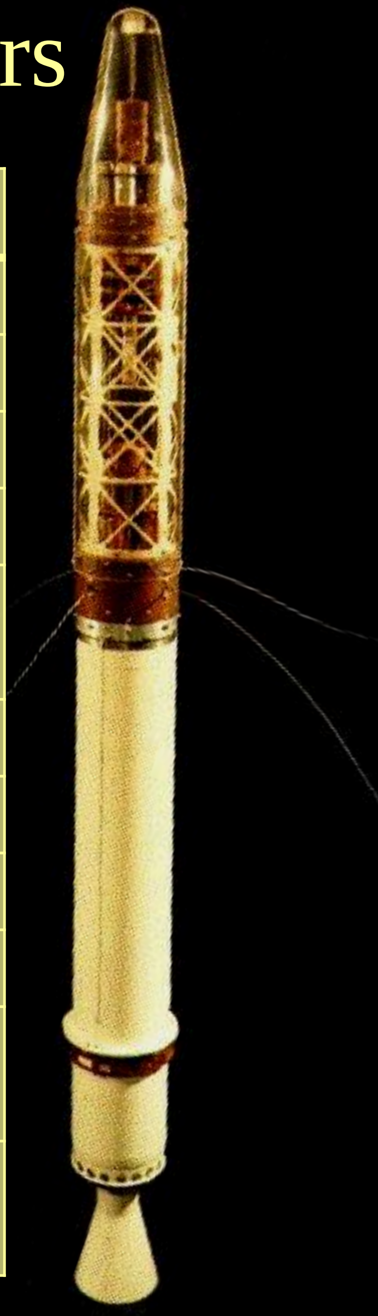
January 4th, 2015:

$$\theta^*_{Earth} = 0°$$

$$\theta^*_{Mars} = 14.2°$$

Commercial Launch Service Providers

Company	Rocket(s)
Boeing Launch Services (BLS)	Delta rockets, Sea Launch
SpaceX	Falcon 9
Orbital Sciences Corp.	Antares
Scaled Composites / Virgin Galactic	WhiteKnightTwo
EADS SPACE Transportation / Arianespace	Ariane Rockets
International Launch Services (ILS)	Proton rocket
United Launch Alliance (ULA)	Delta IV, Atlas V
Soyuz company (Starsem)	Soyuz launch vehicle
Indian Space Research Organisation	PSLV, GSLV
China Great Wall Industry Corporation	**Long March**
Others http://en.wikipedia.org/wiki/List_of_private_spaceflight_companies	



For more information about each rocket, see http://www.astronautix.com/lvs/index.htm.

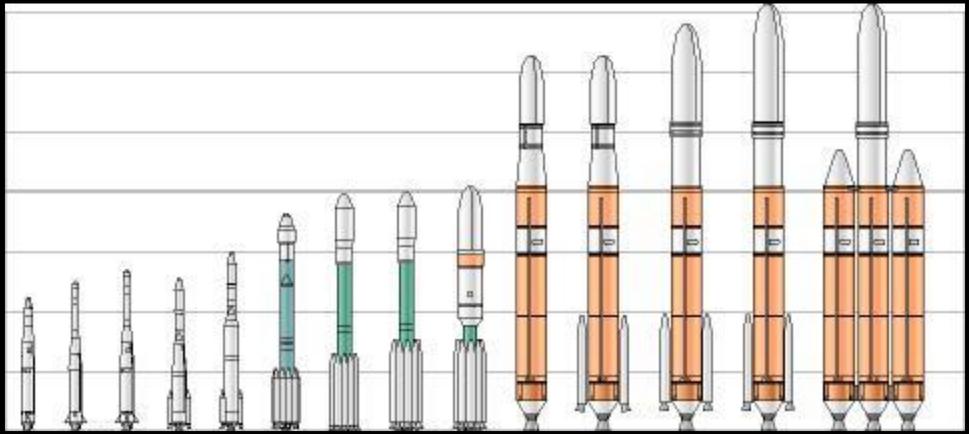
Delta IV Heavy

Status: Active.

Heavy lift all-cryogenic launch vehicle using two Delta-4 core vehicles as first stage flanking a single core vehicle as second stage. A heavy upper stage is carried with a 5 m diameter payload fairing.

Launches: 5. First Launch Date: 2004-12-21. Last Launch Date: 2011.01.20.

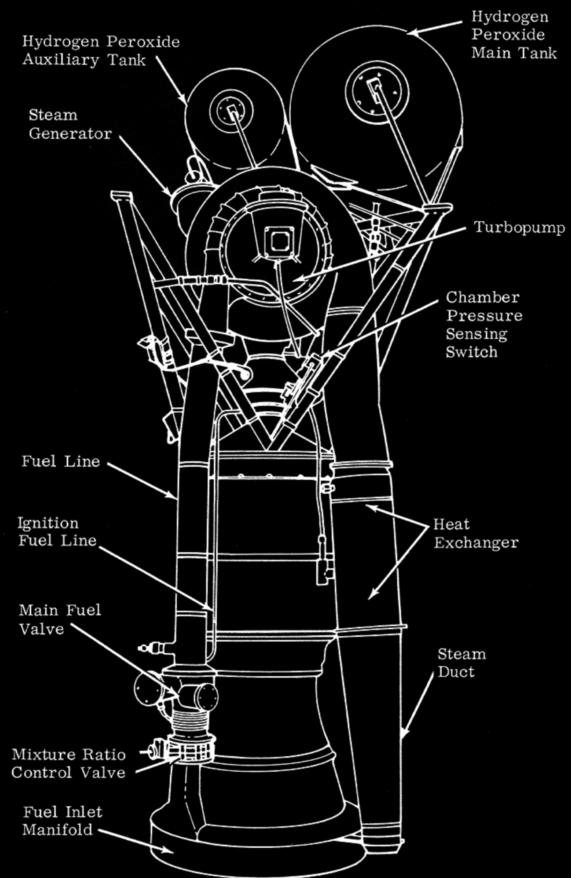
LEO Payload: 25,800 kg (56,800 lb) to 185 km Orbit at 28.50 degrees.
Payload: 10,843 kg (23,904 lb) to a Geosynchronous transfer, 27deg inclination trajectory.
Liftoff Thrust: 8,670.000 kN (1,949,090 lbf).
Total Mass: 733,400 kg (1,616,800 lb). C
Core Diameter: 5.00 m (16.40 ft).
Total Length: 70.70 m (231.90 ft).
Span: 15.00 m (49.00 ft).
Development Cost $: 500.000 million in: 2002 average dollars.
Launch Price $: 254.000 million in: 2004 price dollars.



See: http://www.astronautix.com/lvs/delheavy.htm

Info on costs:
http://www.astronautix.com/articles/costhing.htm

Rocket Engines



http://history.nasa.gov/diagrams/mercury.htm

Moderate Impulse Engines

Characteristic	HM7A	HM7B	VINCI	LE-5	LE-5A	RL10	RL10A-3-3A	RL10A-4N
Engine cycle	GGC	GGC	EC	GGC	EC	EC	EC	EC
Vacuum thrust (kN)	61.6	62.2	155	100	121.5	66.7	73.4	88.9
Vacuum specific impulse (s)	441.4	444.6	464	442	452	412	444.4	448.9
Overall mixture ratio (-)	4.43	4.56	5.8	5.5/5.6	5.0		5.0	5.5
Propellant density[1] (kg/m³)	311	317	365	354/357	333		333	354
Total mass flow rate (kg/s)	14.2	14.4	33.8	23.1	26.9		16.8	
Length (m)	1.81	2.01	4.2	2.65	2.65		1.78	
Maximum diameter (m)	0,938	0.992	2.1	1.65	1.65	0.9	1.65	
Mission duty cycle (s)	570	735		370	550	482	600	740
Dry mass (kg)	149	155	480	255	245	131	140.5	168
Thrust/weight ratio (-)	42.2	40.9	32.9	40.0	50.6	51.9	54.2	54.0
Restart capability (yes/no)	No	No	Yes	Yes	Yes	No	No	Yes
1st flight (yr)	1979	1983	2005	1986	1994	1961	1984	1991

Data from: http://www.lr.tudelft.nl/index.php?id=26229&L=1#1

More on fuels and specific impulse: www.braeunig.us/space/propel.htm#liquid
More small rocket engines: http://www.astronautix.com/props/index.htm
Additional engine performance tables: http://www.lr.tudelft.nl/index.php?id=26229&L=1#1

Useful Information: Life Support

Daily Life Support Requirements per person	
Input	**Output**
1.4 lbs of food	3.3 lbs of urine
7-9 lbs of water	4.0 lbs of metabolic water
2 lbs of oxygen	2.2 lbs of CO_2
	0.4 lbs of solid waste

Source: http://web.mit.edu/12.000/www/finalpresentation/environment/lifesupport.html

Also has additional information about astronaut safety considerations.

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Questions to Consider

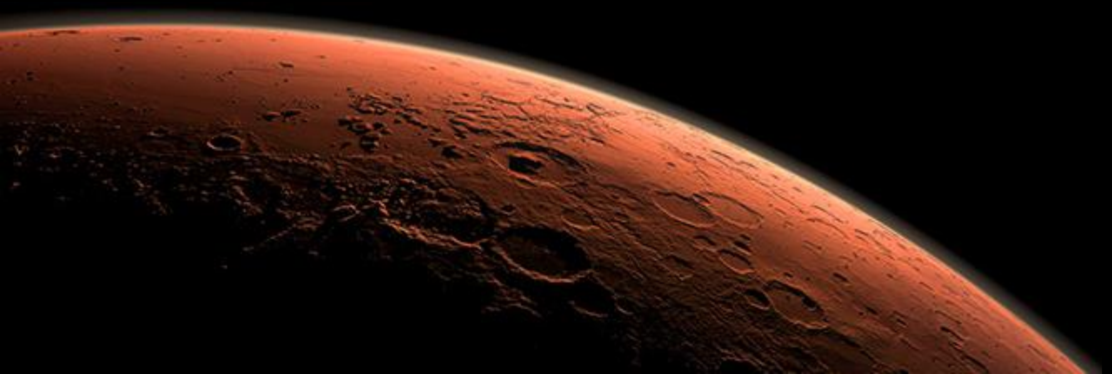
- How can you find an optimal solution?
- How much should be charged for lab fees? Costs include:
  - Commercial launch to LEO
  - Propulsion systems
  - Fuel
  - Food
  - Engineering costs?
  - Others?

- What technologies or capabilities must be developed to make the mission more feasible?
  - You could re-run your analysis based on these.

Questions to Consider, Cont.

- What is the probability of a successful mission?
- If the trip is long (more efficient), how are the astronauts to be protected from radiation? Other important considerations?

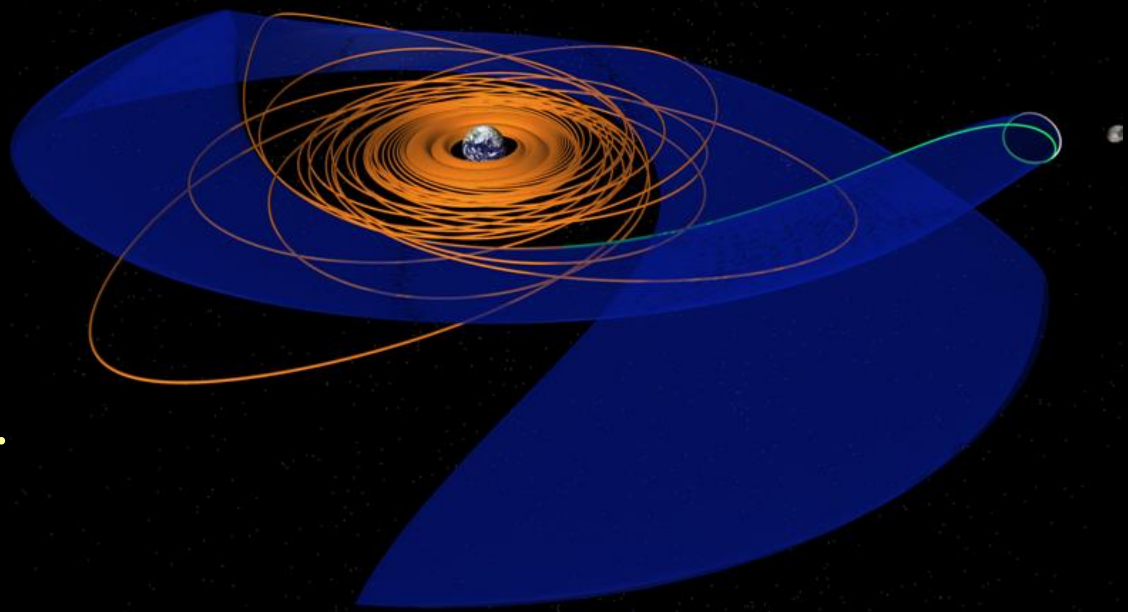
If you have ideas/questions about something that I did not think of, please come talk to me! Your creativity is strongly encouraged on this assignment.



Outcomes

1. Experience: open-ended assignment that you do not know much about initially → happens all the time!

2. Practice:
   - Octave
   - giving a technical presentation.
   - working as a team.



3. Appreciation for:
   - space mission design
   - razor-thin margins involved!

Additional Useful Resources

Rocket and Space Technology
Includes info on rockets and orbital mechanics

Delta V Budgets – may be useful to read through, in planning (or assessing) your mission design.

Cool NASA Spacecraft Drawings

General Rocket Engine Information:
Propulsion Information - Purdue University
PROPELLANTS
Rocket Propellants
Performance data of some typical liquid rocket engines

Launch Systems end Rocket Engines:
Encyclopedia Astronautica
The Spacecrafts Encyclopedia
Kaiser Marquardt Rocket Engines
Marquardt Rockets Info
Artemis Project Rocket Engine Specifications
Atlas Centaur LV-3C Development
The Titan Launch Vehicle -- see p. 32

Calculating Orbits:
Computing planetary positions
How Orbital Motion is Calculated
NEAR-EARTH ASTEROID TRACKING
Planet positions using elliptical orbits

Current Manned Mars Exploration Plans and News
NASA Deep Sleep Option for Mars Mission
Time to Get Serious About Going to Mars, NASA Says
Manned Mission to Mars by 2030s Is Really Possible, Experts Say
Wikipedia Article
The Mars Society – purpose is to "further the exploration and settlement of the Red Planet."

Software:
Bipropellant Rocket Calculator
Pumped Rocket Calculator
Rocket Cost Calculator
Tripropellant Rocket Calculator
Launch Calculation Applet
botec Orbit Calculator

Books (I have a copy of each):
Fundamentals of Astrodynamics
Roger R. Bate, Donald D. Mueller, and Jerry E. White, Dover (1972)

Space Propulsion Analysis and Design
Ronald W. Humble, Gary N. Henry, Wiley J. Larson, Learning Solutions (2007)

Mission to Mars: My Vision for Space Exploration
Buzz Aldrin, National Geographic (2013)

Indian Space Research Association – Mars Orbiter Mission Overview
The Frugal Innovation
Minimum cost, to date – only $73-74 million

Papers:
Mars Free Return Trajectories
M. R. Patel, J. M. Longuski, and J. A. Sims,
Journal of Spacecraft and Rockets, 35 (3), 1998.

Mission Opportunities for Human Exploration of Nearby Planetary Bodies
C. Foster and M. Daniels, AIAA Paper No. 2010-8609, 2010.
(Includes results for Mars Rendevous missions among others.)

Mission Design Options for Human Mars Missions
P. D. Wooster, R. D. Braun, J. Ahn, Z. R. Putnam,
Int. J. of Mars Science and Exploration, 3, pp. 12-28, 2007.

Radiation Effects and Shielding Requirements in Human Missions to the Moon and Mars
D. Rapp, Int. J. Mars Science and Exploration, 2, pp. 46-71, 2006.

Planetary Protection Issues in the Human Exploration of Mars
M. E. Criswell, M. S. Race, J. D. Rummel, A. Baker,
NASA CP 2005-213461.

A Compilation of Lunar and Mars Exploration Strategies Utilizing Indigenous Propellants
D. L. Linne and M. L. Meyer, NASA TM 105262, 1992.