Mars Sample Return Project: Rigel

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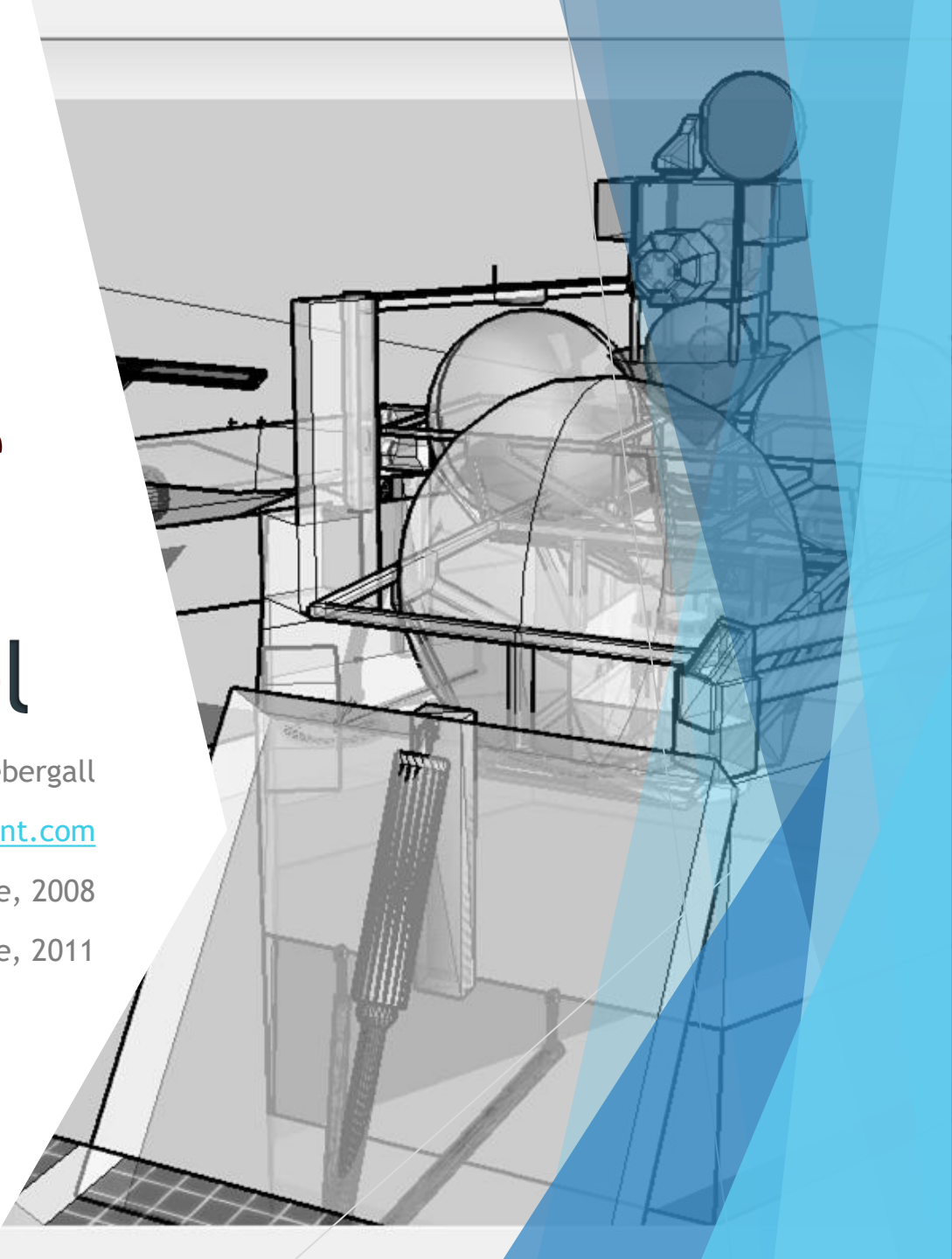
Mars Society Conference, 2008

International Space Development Conference, 2011



Design Criteria (MarsDrive Competition)

- Minimal Cost (under $2 billion USD FY2008)
- In Situ Propellant Production
- Planetary Protection of Mars
- Planetary Protection of Earth

Rigel Solutions

- Used flown or then-flown components, when possible, remainder simplified as much as possible
- Use of Mars Science Laboratory aeroshell
- Ethylene/Oxygen propellant production using solar power

Basic Math

Bounding Calculations

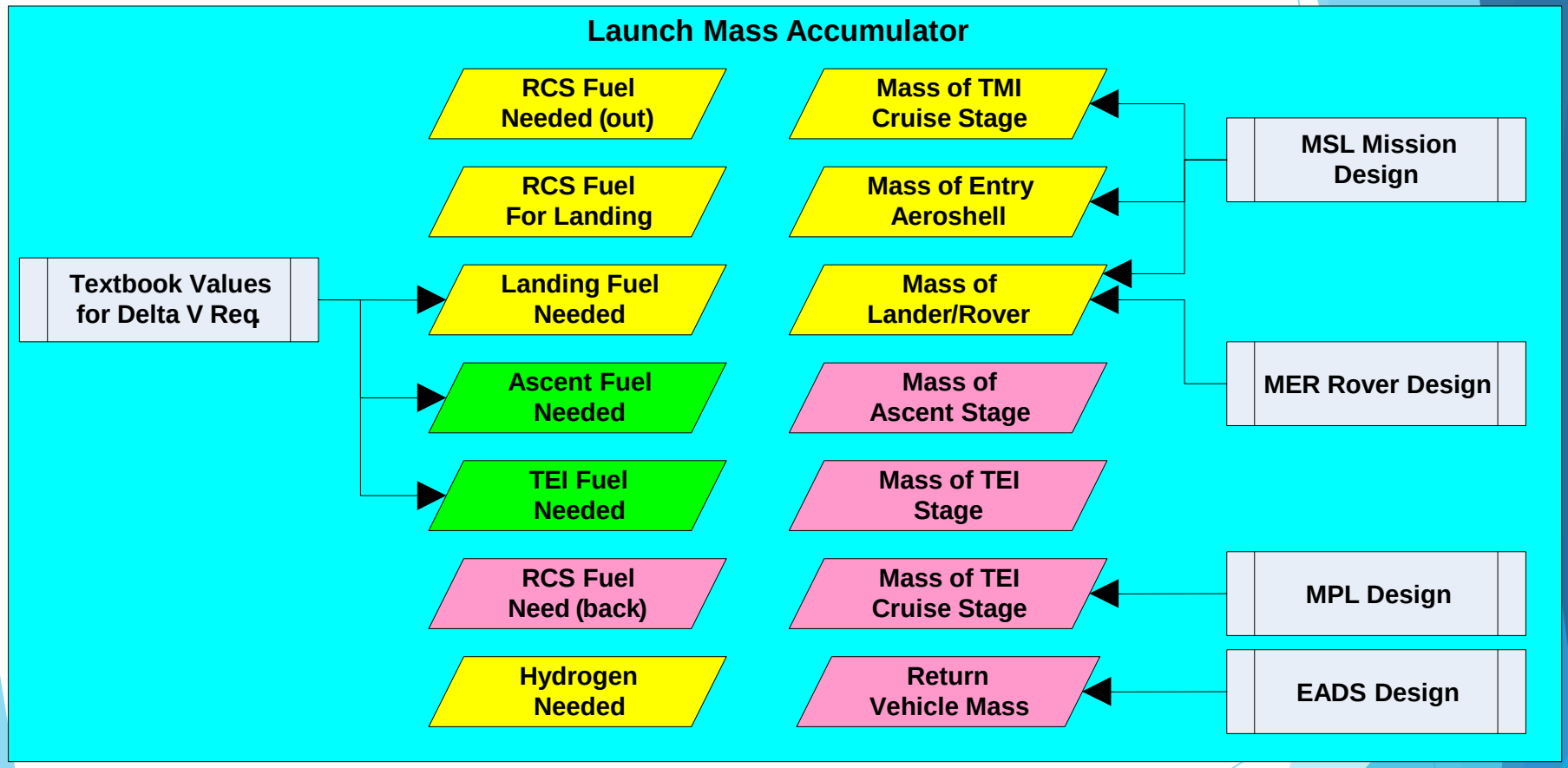
Main Spreadsheet

- Factors 20 different designs of different scales
- Over 6000 cells for direct calculations
  - Some rows calculated iteratively on other pages and copied in for inclusion in the whole
- After initial work, further iterations refined competitive designs (SSTO versus 2nd stage circularization, etc.).
- Finally, more realistic margins are placed on the design to reflect engineering realities.

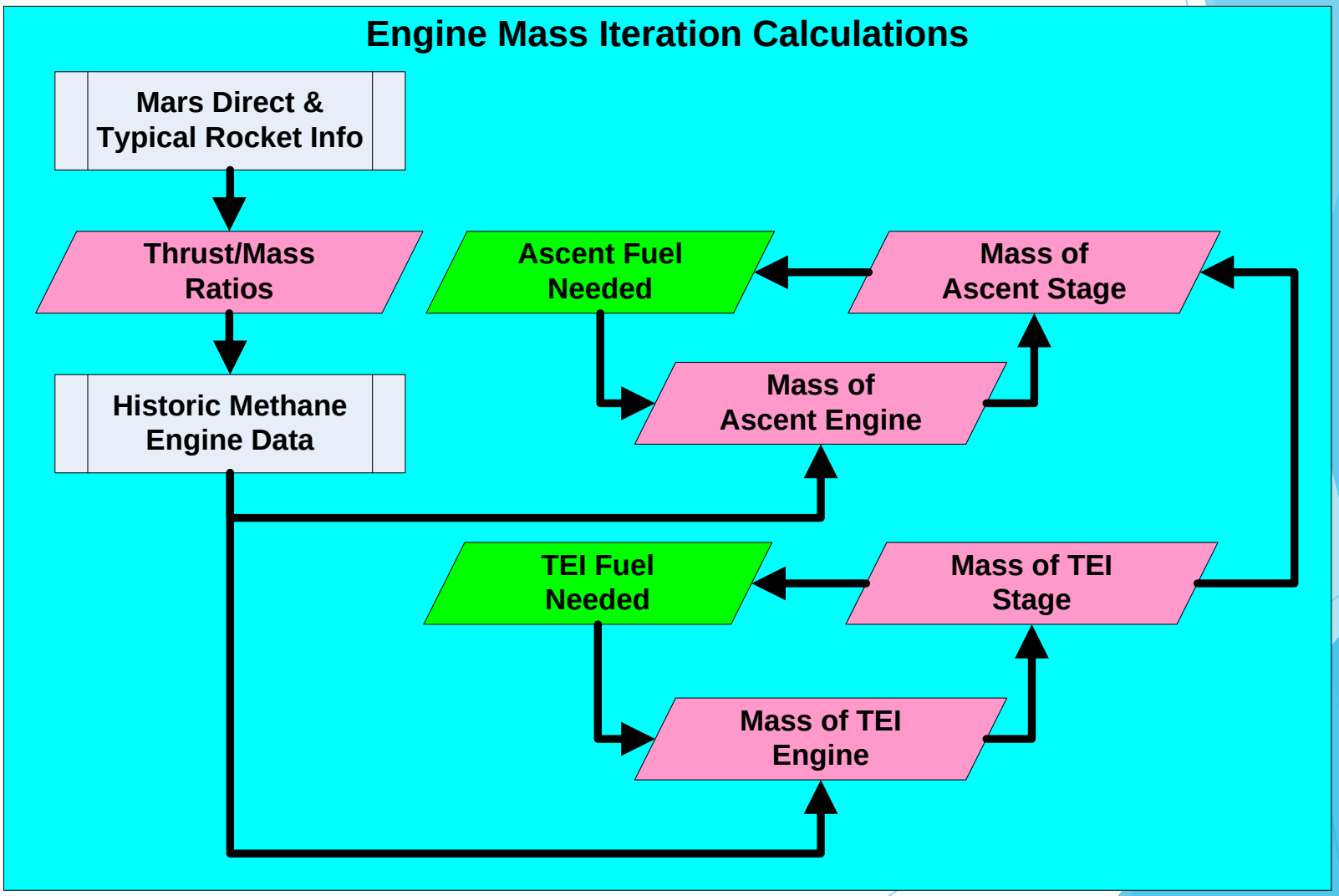
The Rocket Equation

Mass Before Burn	• Dry Mass After Landing
Mass After Burn	• Wet Mass With Fuel Load
Delta-V	• Known Value for Landing, Ascent, and Trans-Earth Injection
ISP (Specific Impulse)	• Known Value for Various Propellants

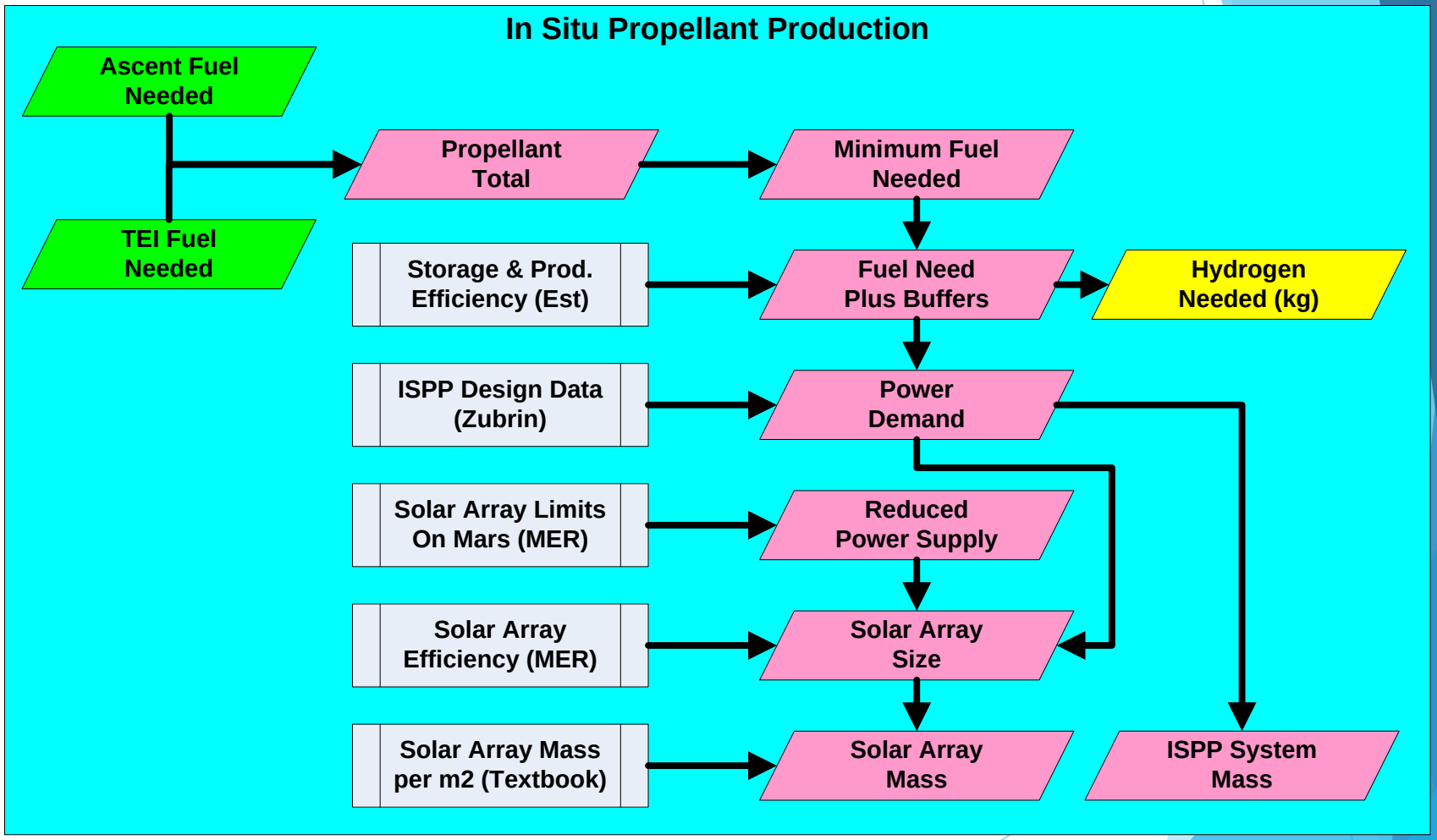
Launch Payload Mass Factors

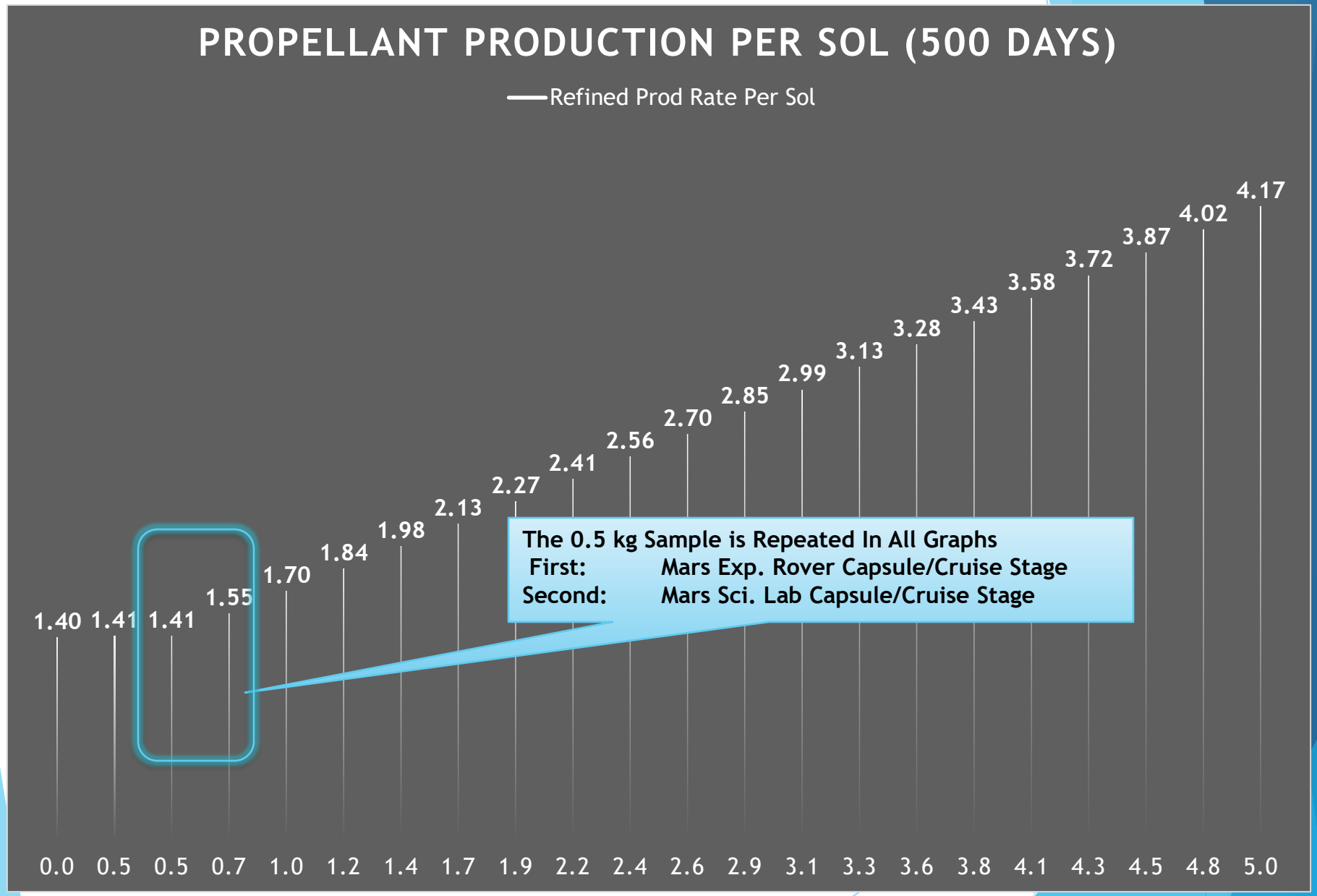


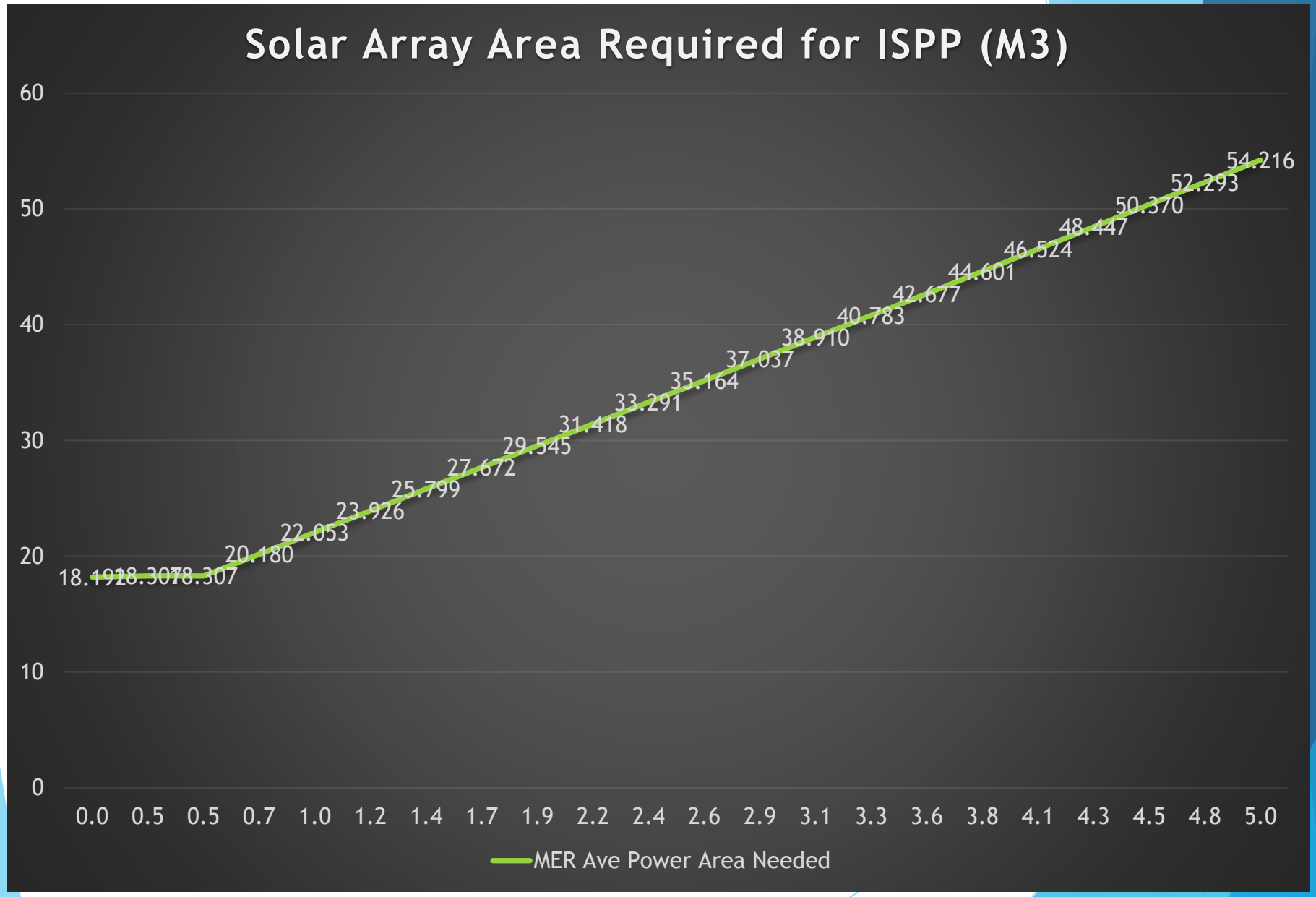
Engine Mass: Iterative Work



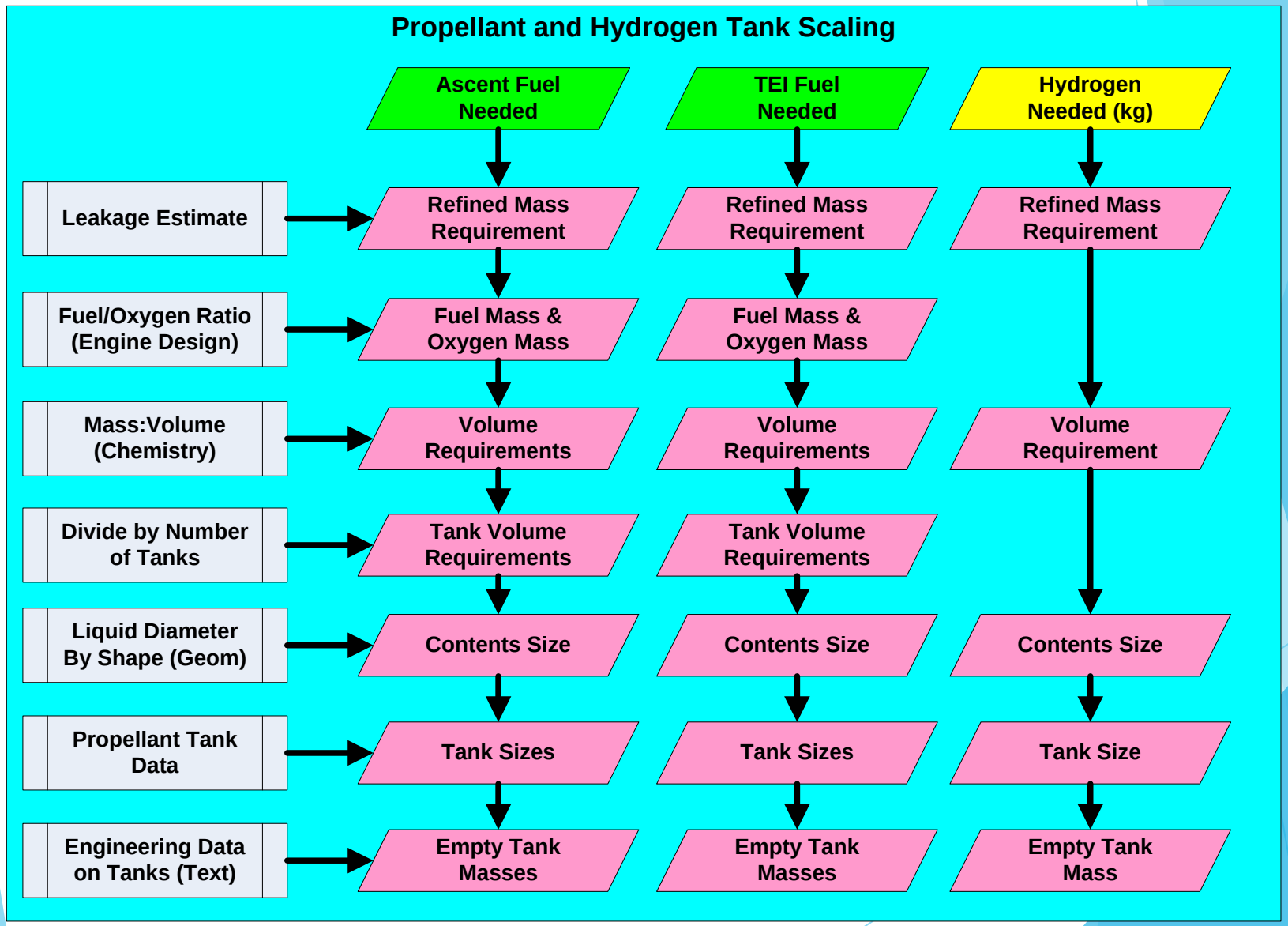
Propellant Supply & Demand

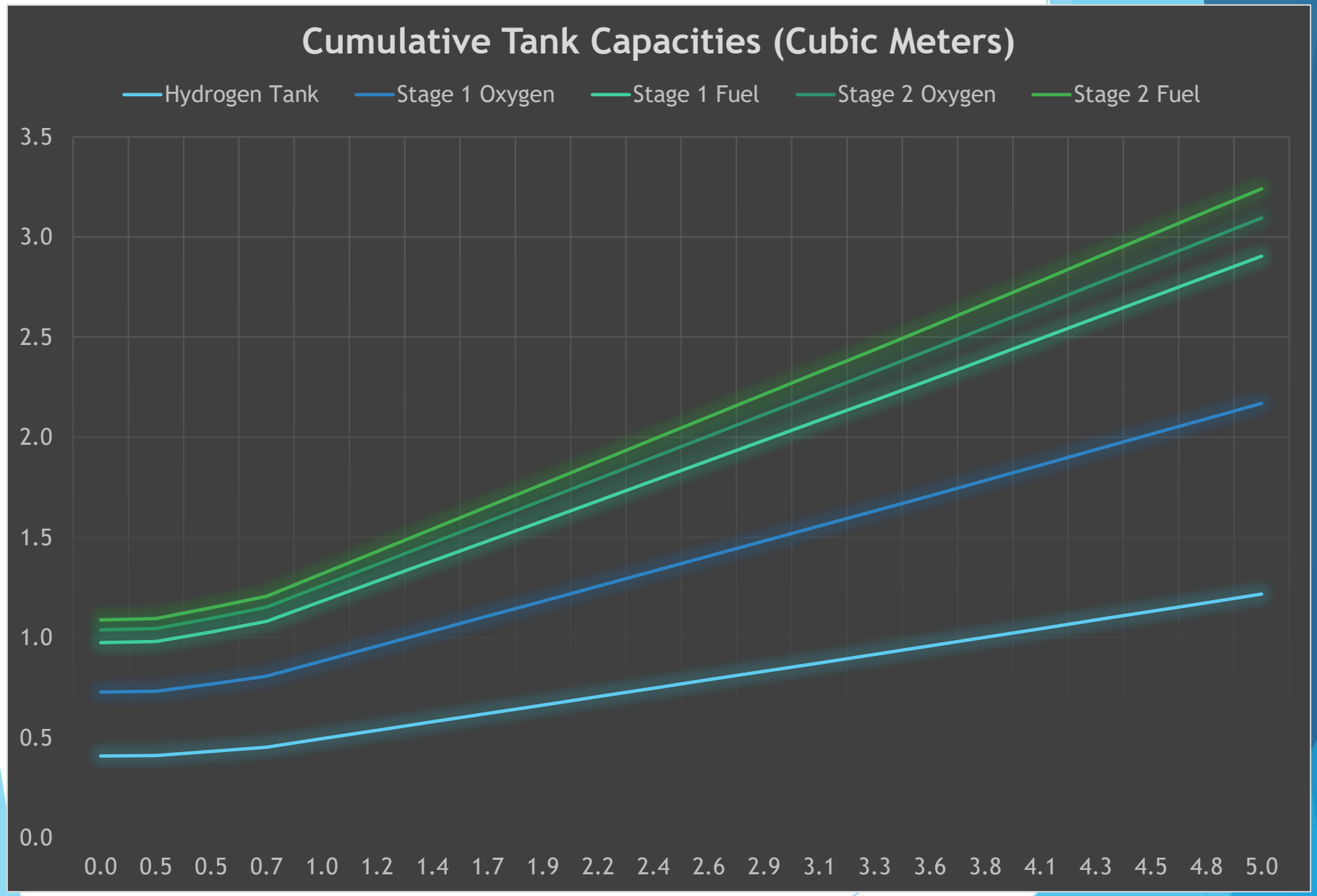


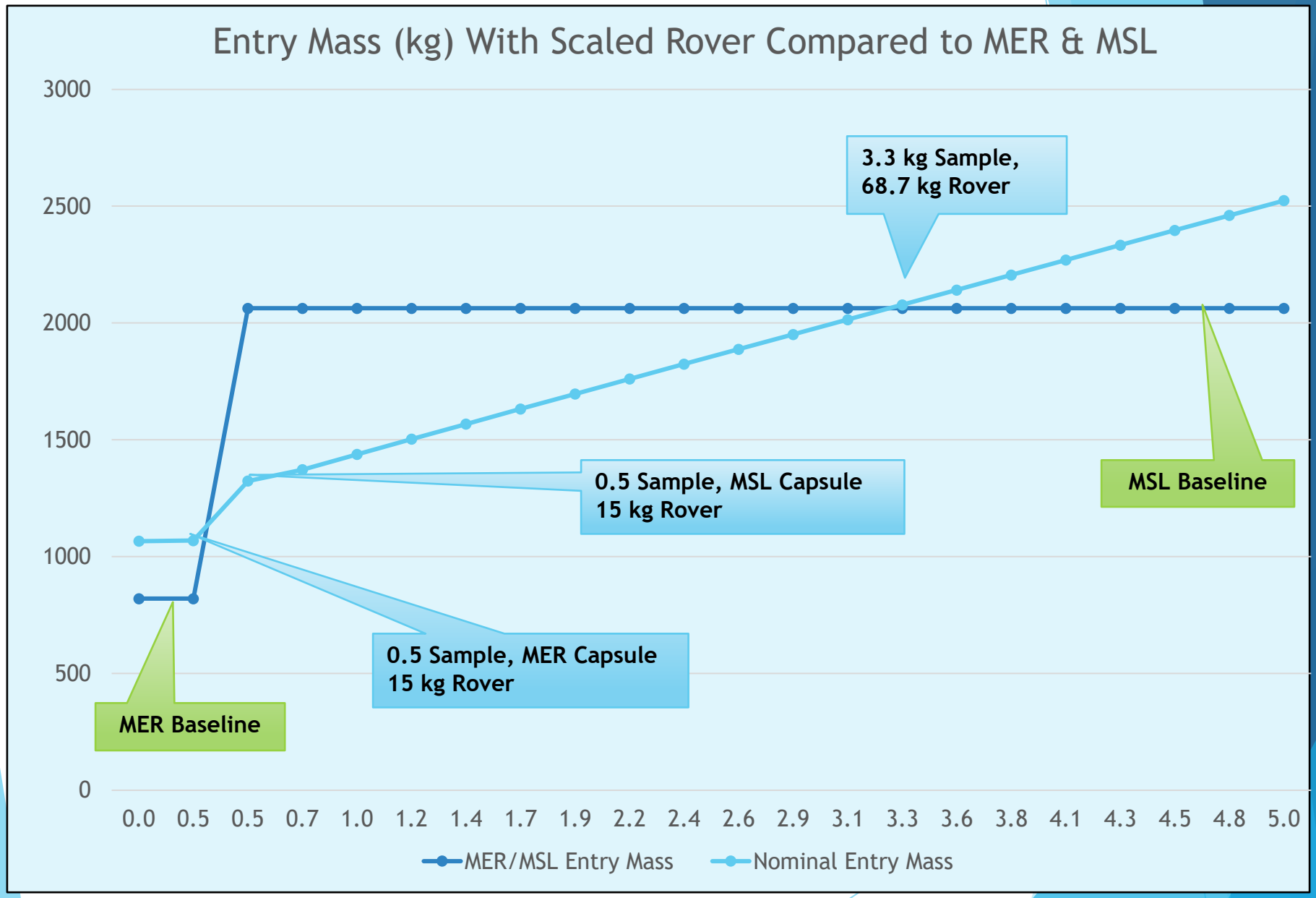

PROPELLANT PRODUCTION PER SOL (500 DAYS)
Refined Prod Rate Per Sol
1.40
1.41
1.41
1.55
1.70
1.84
1.98
2.13
2.27
2.41
2.56
2.70
2.85
2.99
3.13
3.28
3.43
3.58
3.72
3.87
4.02
4.17
0.0
0.5
0.5
0.7
1.0
1.2
1.4
1.7
1.9
2.2
2.4
2.6
2.9
3.1
3.3
3.6
3.8
4.1
4.3
4.5
4.8
5.0
The 0.5 kg Sample is Repeated In All Graphs
First: Mars Exp. Rover Capsule/Cruise Stage
Second: Mars Sci. Lab Capsule/Cruise Stage

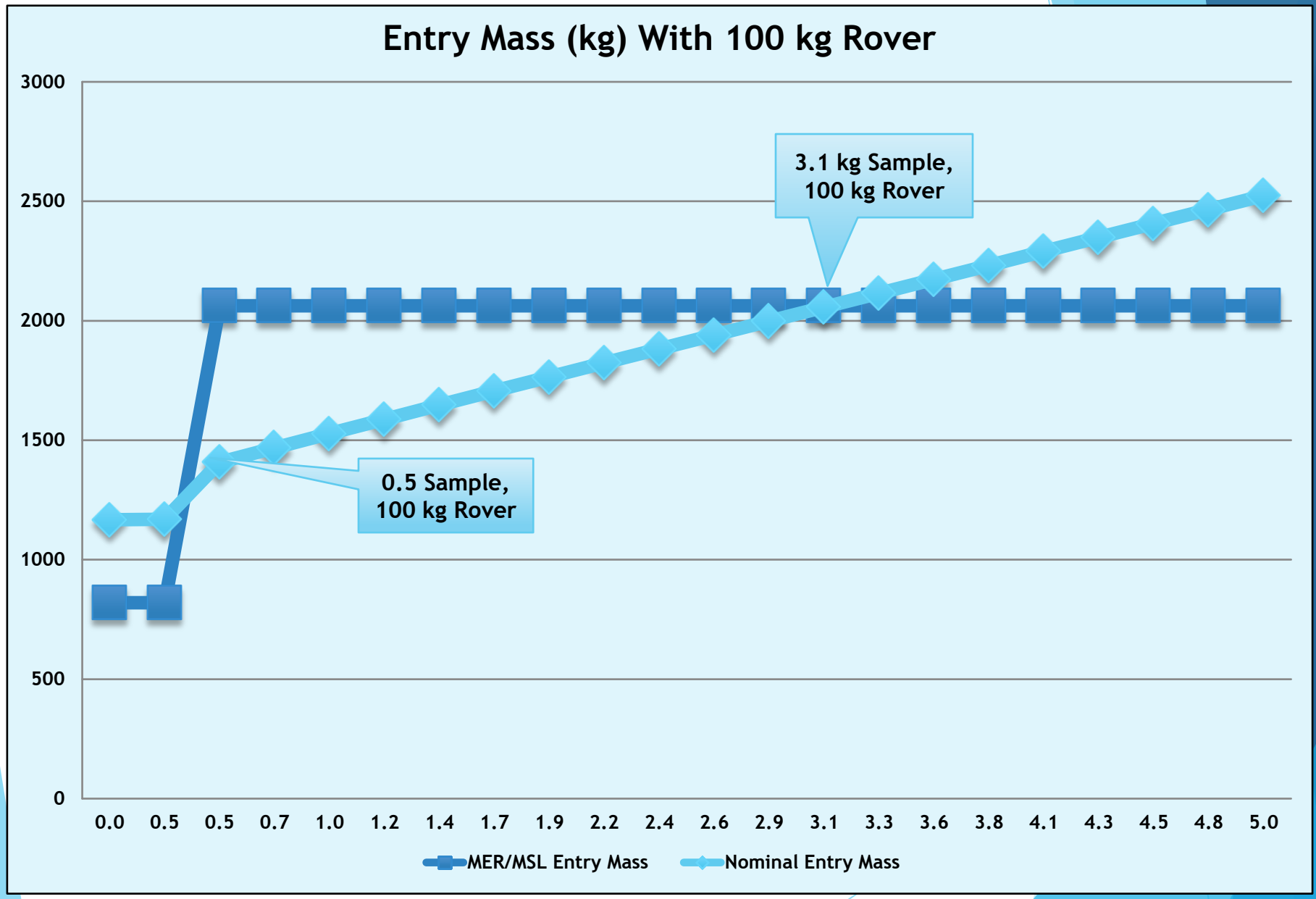

Solar Array Area Required for ISPP (M3)
60
50
40
30
20
10
0
18.192
18.307
18.307
20.180
22.053
23.926
25.799
27.672
29.545
31.418
33.291
35.164
37.037
38.910
40.783
42.677
44.601
46.524
48.447
50.370
52.293
54.216
0.0 0.5 0.5 0.7 1.0 1.2 1.4 1.7 1.9 2.2 2.4 2.6 2.9 3.1 3.3 3.6 3.8 4.1 4.3 4.5 4.8 5.0
MER Ave Power Area Needed

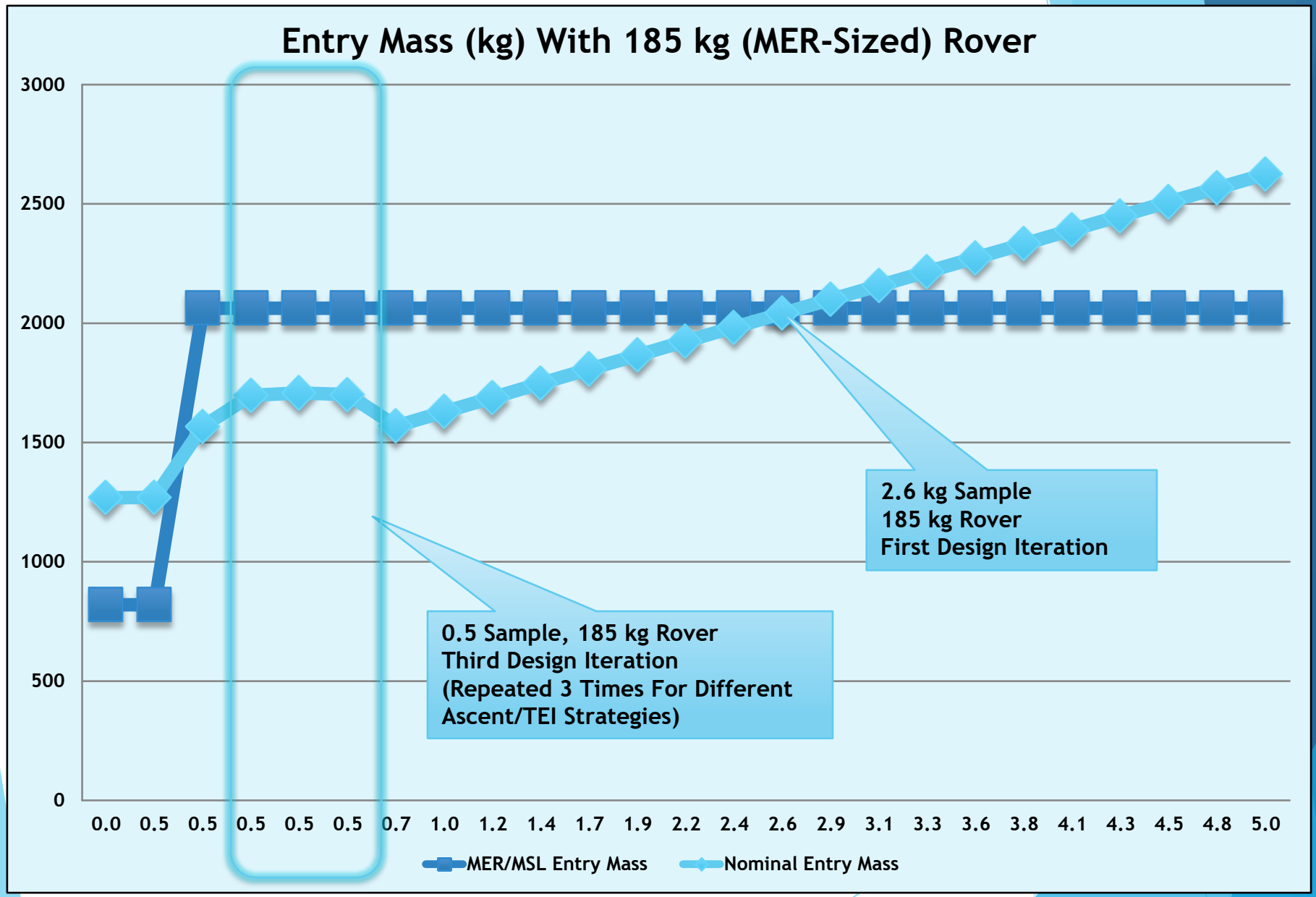
Tank Sizing


Propellant and Hydrogen Tank Scaling
Ascent Fuel Needed
TEI Fuel Needed
Hydrogen Needed (kg)
Leakage Estimate
Refined Mass Requirement
Refined Mass Requirement
Refined Mass Requirement
Fuel/Oxygen Ratio (Engine Design)
Fuel Mass & Oxygen Mass
Fuel Mass & Oxygen Mass
Mass:Volume (Chemistry)
Volume Requirements
Volume Requirements
Volume Requirement
Divide by Number of Tanks
Tank Volume Requirements
Tank Volume Requirements
Liquid Diameter By Shape (Geom)
Contents Size
Contents Size
Contents Size
Propellant Tank Data
Tank Sizes
Tank Sizes
Tank Size
Engineering Data on Tanks (Text)
Empty Tank Masses
Empty Tank Masses
Empty Tank Mass


Cumulative Tank Capacities (Cubic Meters)
Hydrogen Tank
Stage 1 Oxygen
Stage 1 Fuel
Stage 2 Oxygen
Stage 2 Fuel
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0 0.5 0.5 0.7 1.0 1.2 1.4 1.7 1.9 2.2 2.4 2.6 2.9 3.1 3.3 3.6 3.8 4.1 4.3 4.5 4.8 5.0


Entry Mass (kg) With Scaled Rover Compared to MER & MSL
3000
2500
2000
1500
1000
500
0
0.0
0.5
0.5
0.7
1.0
1.2
1.4
1.7
1.9
2.2
2.4
2.6
2.9
3.1
3.3
3.6
3.8
4.1
4.3
4.5
4.8
5.0
3.3 kg Sample,
68.7 kg Rover
0.5 Sample, MSL Capsule
15 kg Rover
MSL Baseline
0.5 Sample, MER Capsule
15 kg Rover
MER Baseline
MER/MSL Entry Mass
Nominal Entry Mass


Entry Mass (kg) With 100 kg Rover
3000
2500
2000
1500
1000
500
0
3.1 kg Sample,
100 kg Rover
0.5 Sample,
100 kg Rover
0.0
0.5
0.5
0.7
1.0
1.2
1.4
1.7
1.9
2.2
2.4
2.6
2.9
3.1
3.3
3.6
3.8
4.1
4.3
4.5
4.8
5.0
MER/MSL Entry Mass
Nominal Entry Mass

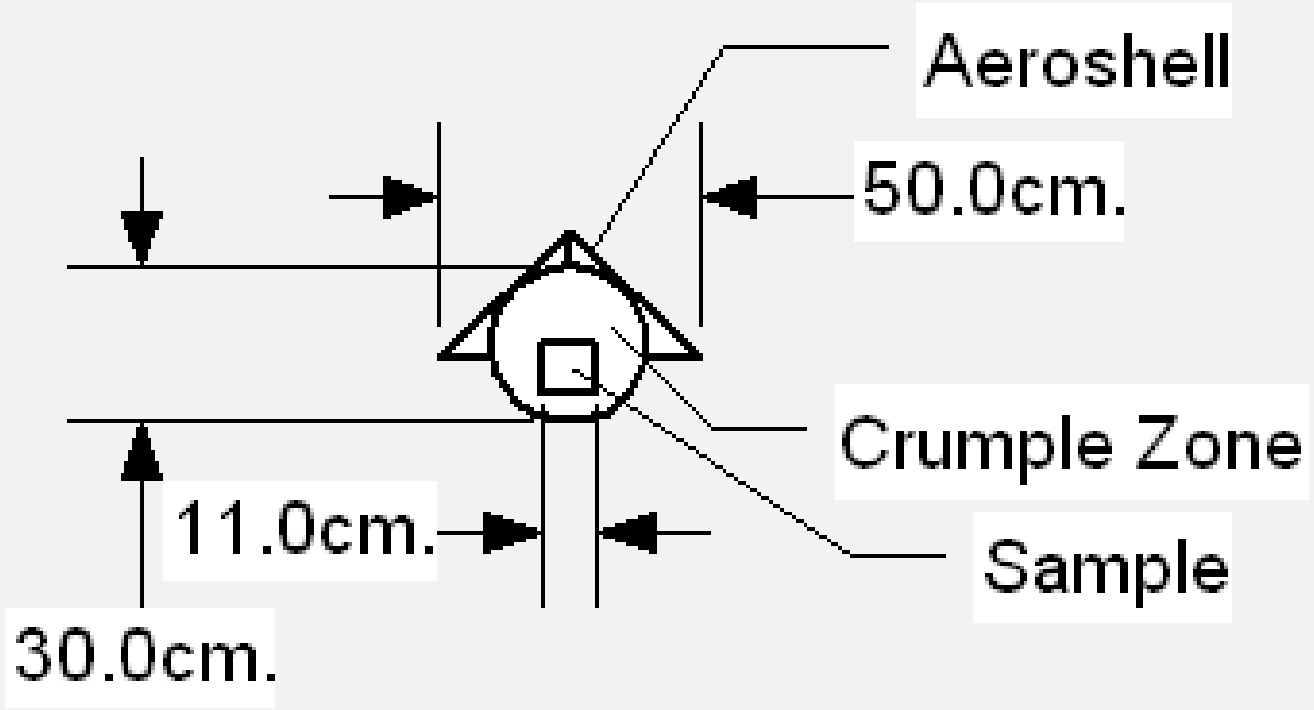

Entry Mass (kg) With 185 kg (MER-Sized) Rover
3000
2500
2000
1500
1000
500
0
0.0 0.5 0.5 0.5 0.5 0.5 0.7 1.0 1.2 1.4 1.7 1.9 2.2 2.4 2.6 2.9 3.1 3.3 3.6 3.8 4.1 4.3 4.5 4.8 5.0
MER/MSL Entry Mass
Nominal Entry Mass
2.6 kg Sample
185 kg Rover
First Design Iteration
0.5 Sample, 185 kg Rover
Third Design Iteration
(Repeated 3 Times For Different
Ascent/TEI Strategies)

Vehicle Design

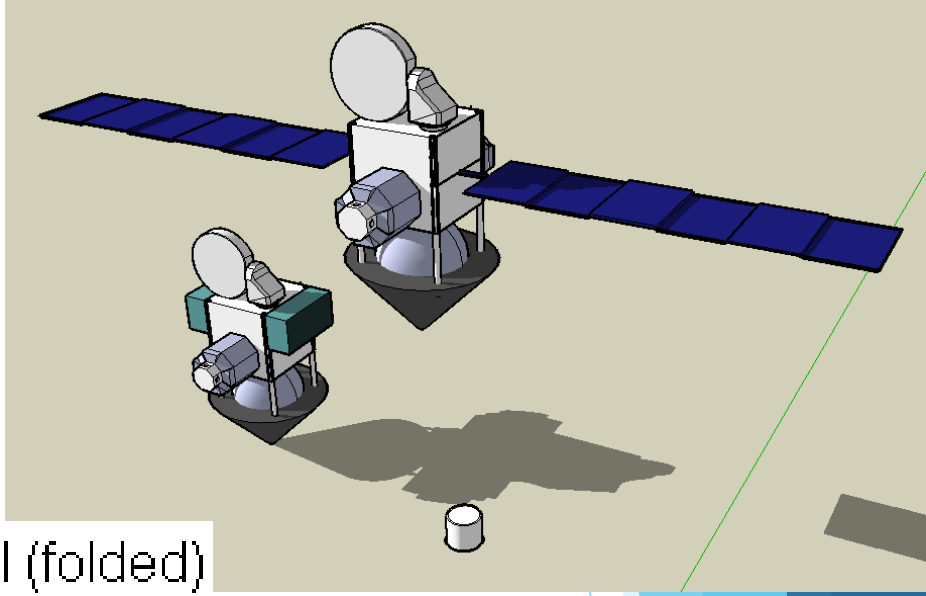
Layout by Stages

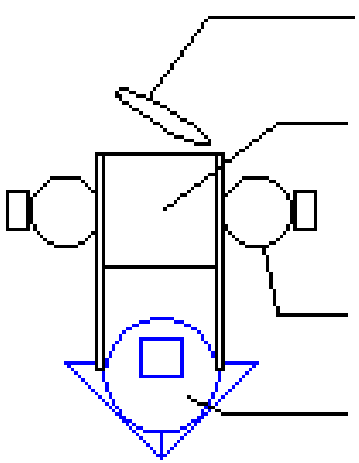
Return Capsule

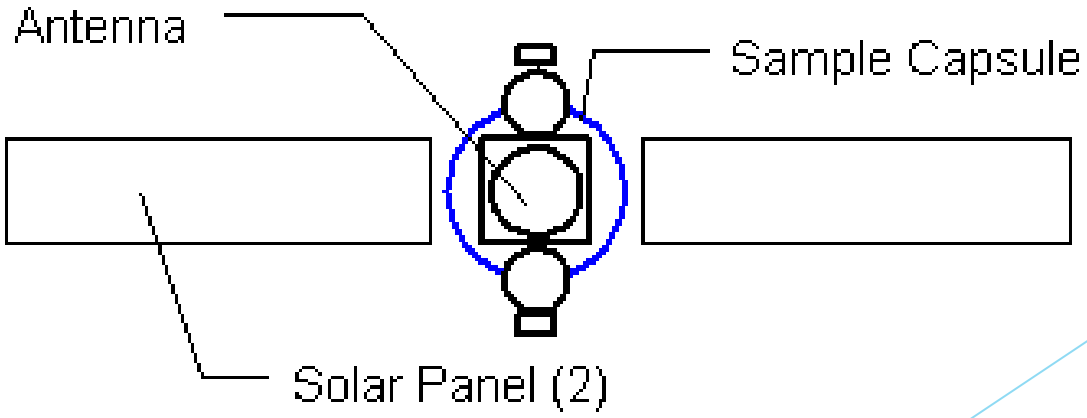
- Capsule has air sample, core sample, and many packaged soil/rock samples



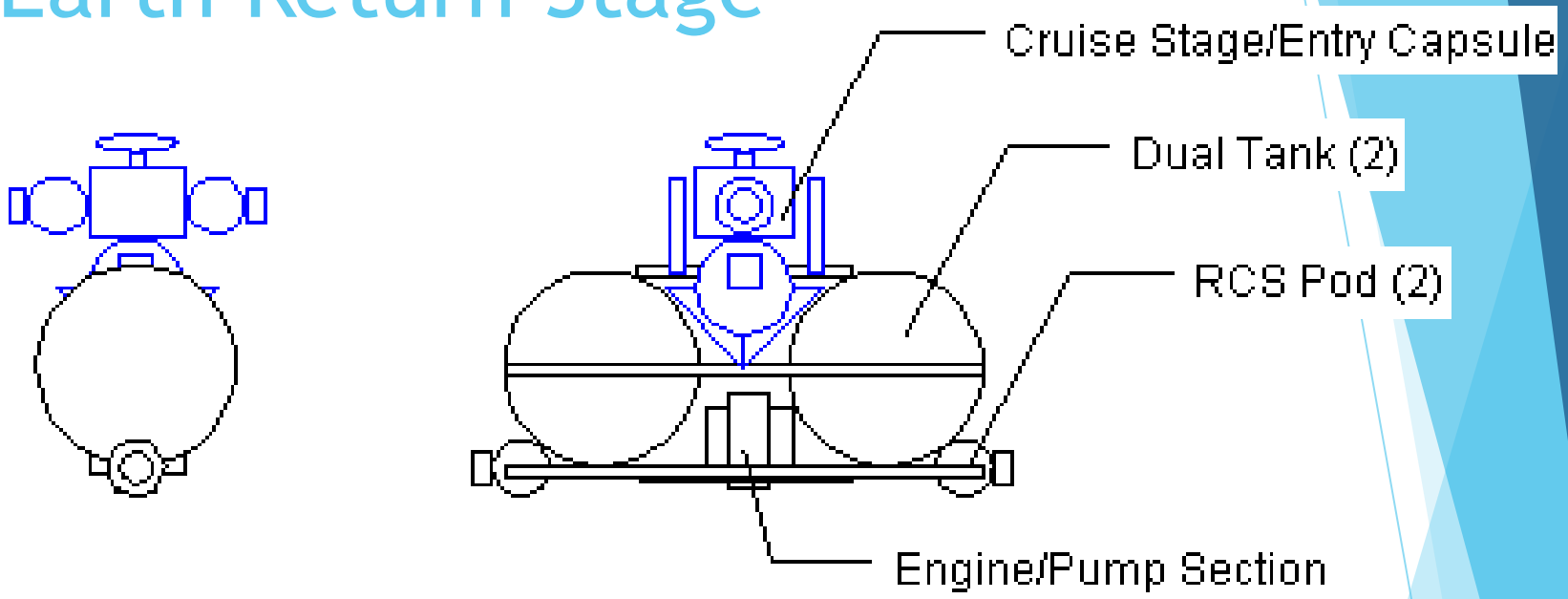
Return Cruise Stage

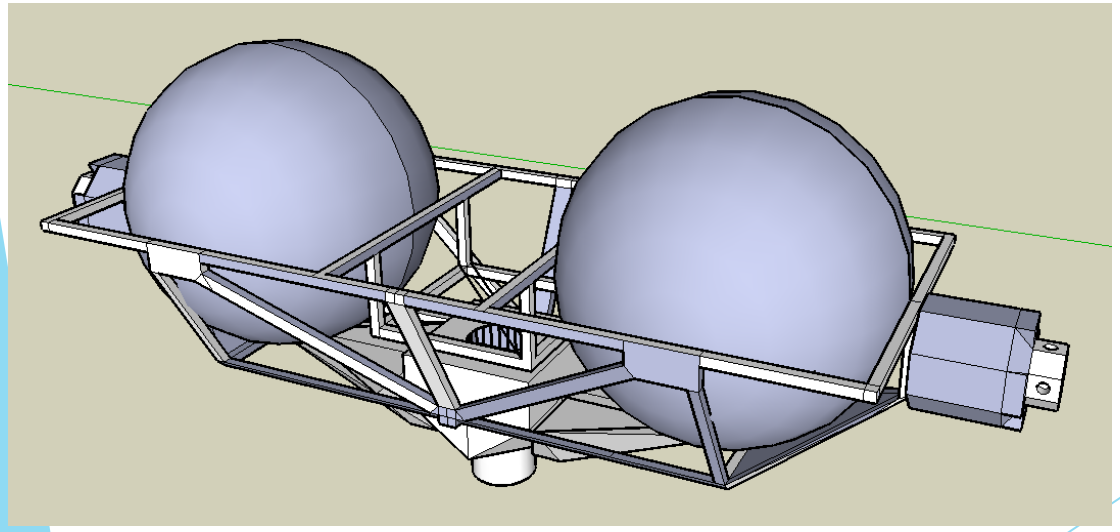




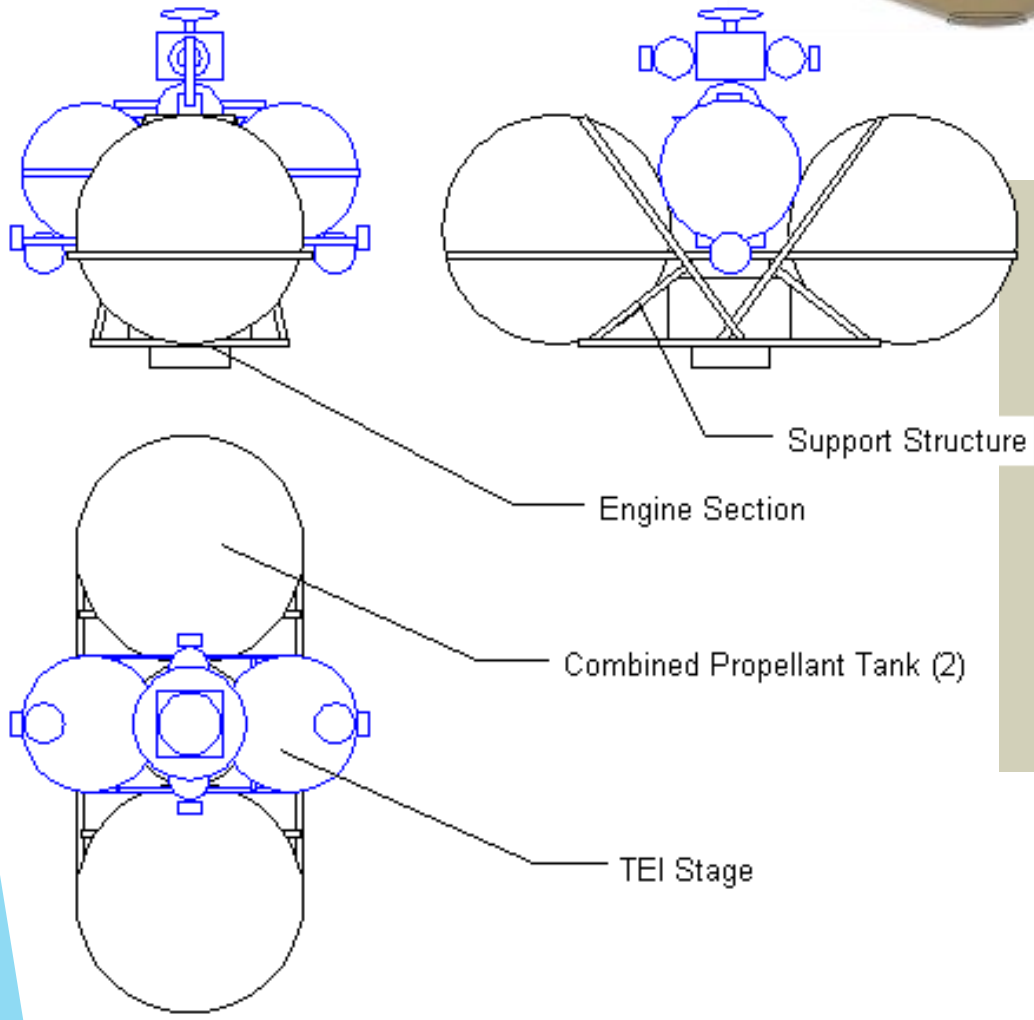


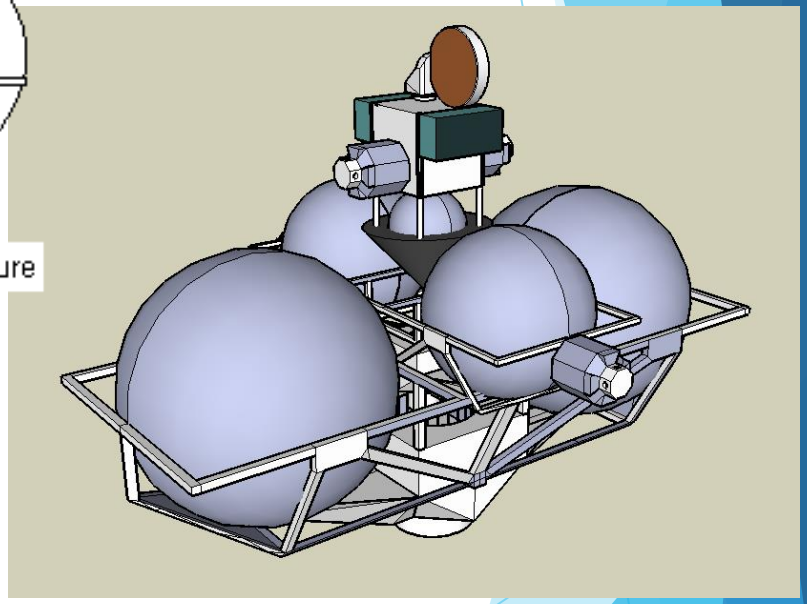
Earth Return Stage



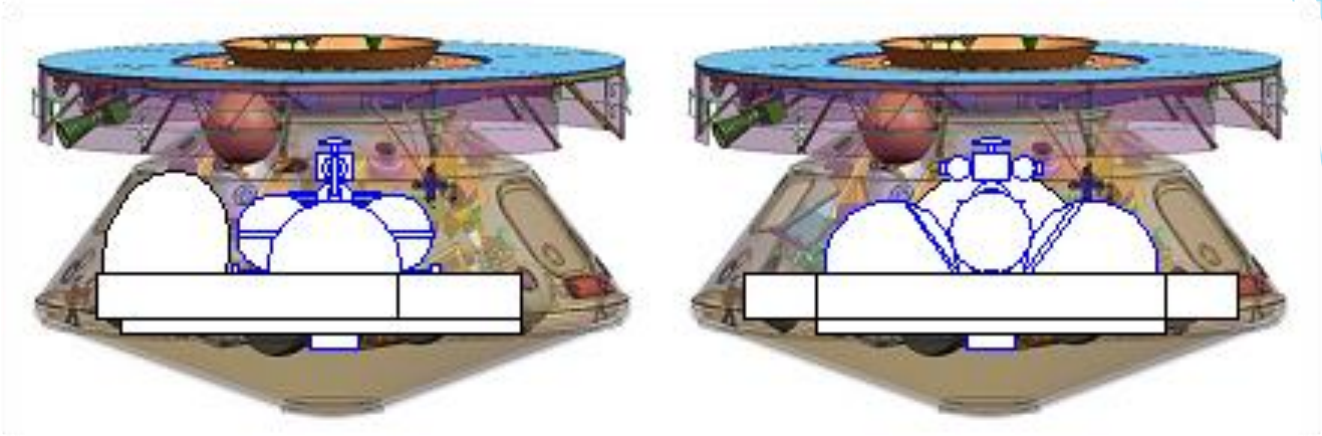


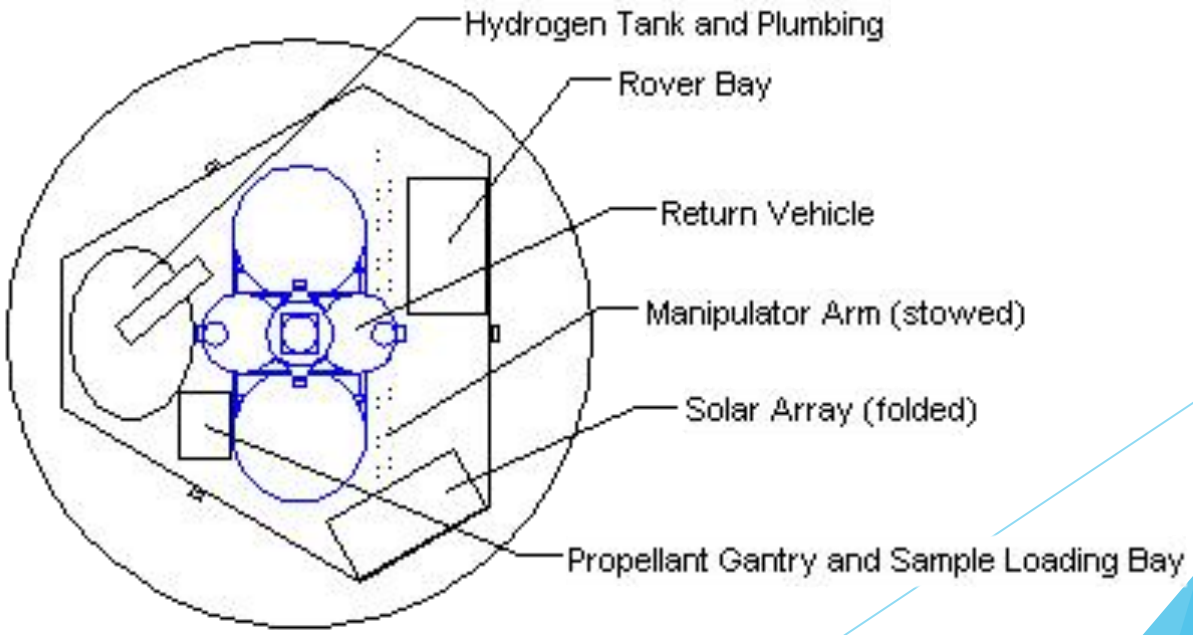
Ascent Stage



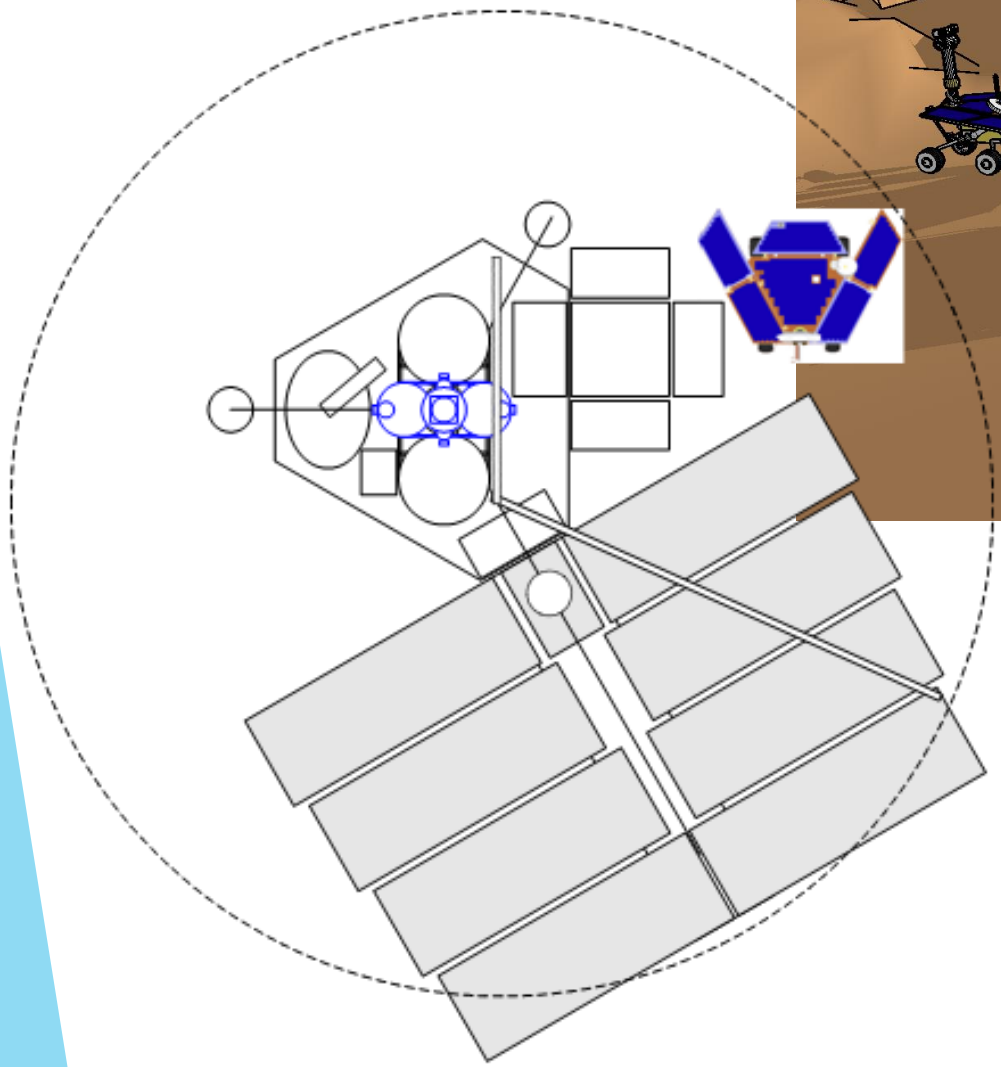


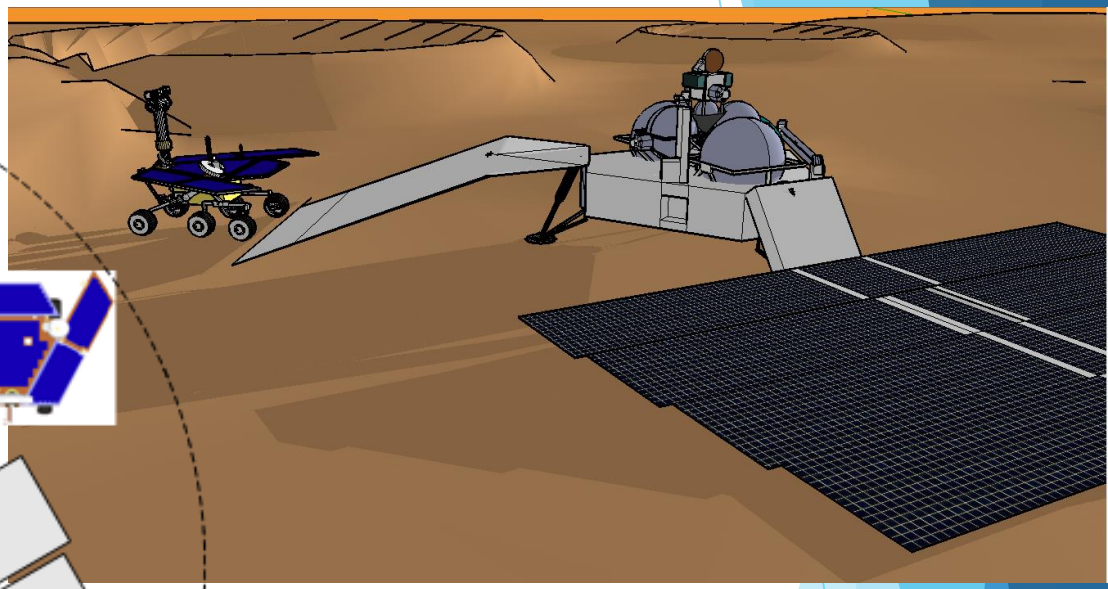
Lander EDL Capsule



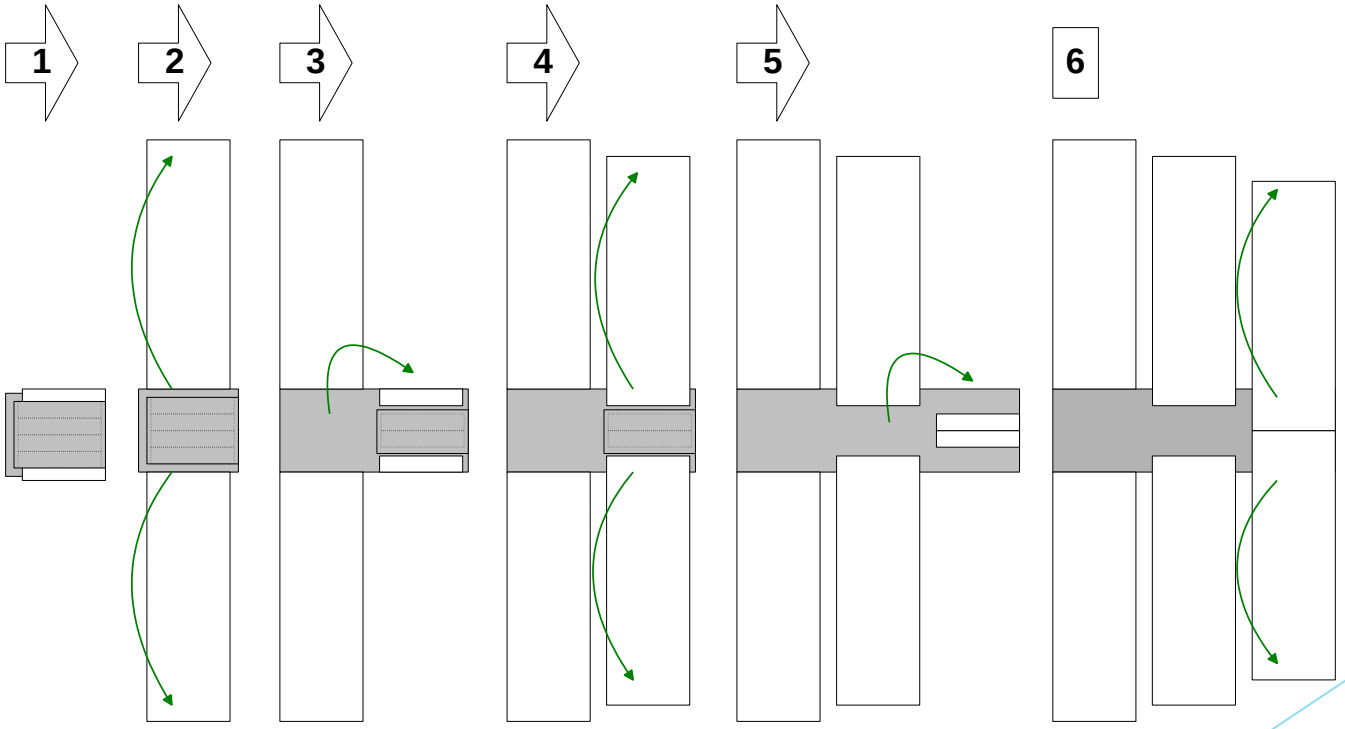


Surface Base with Rover

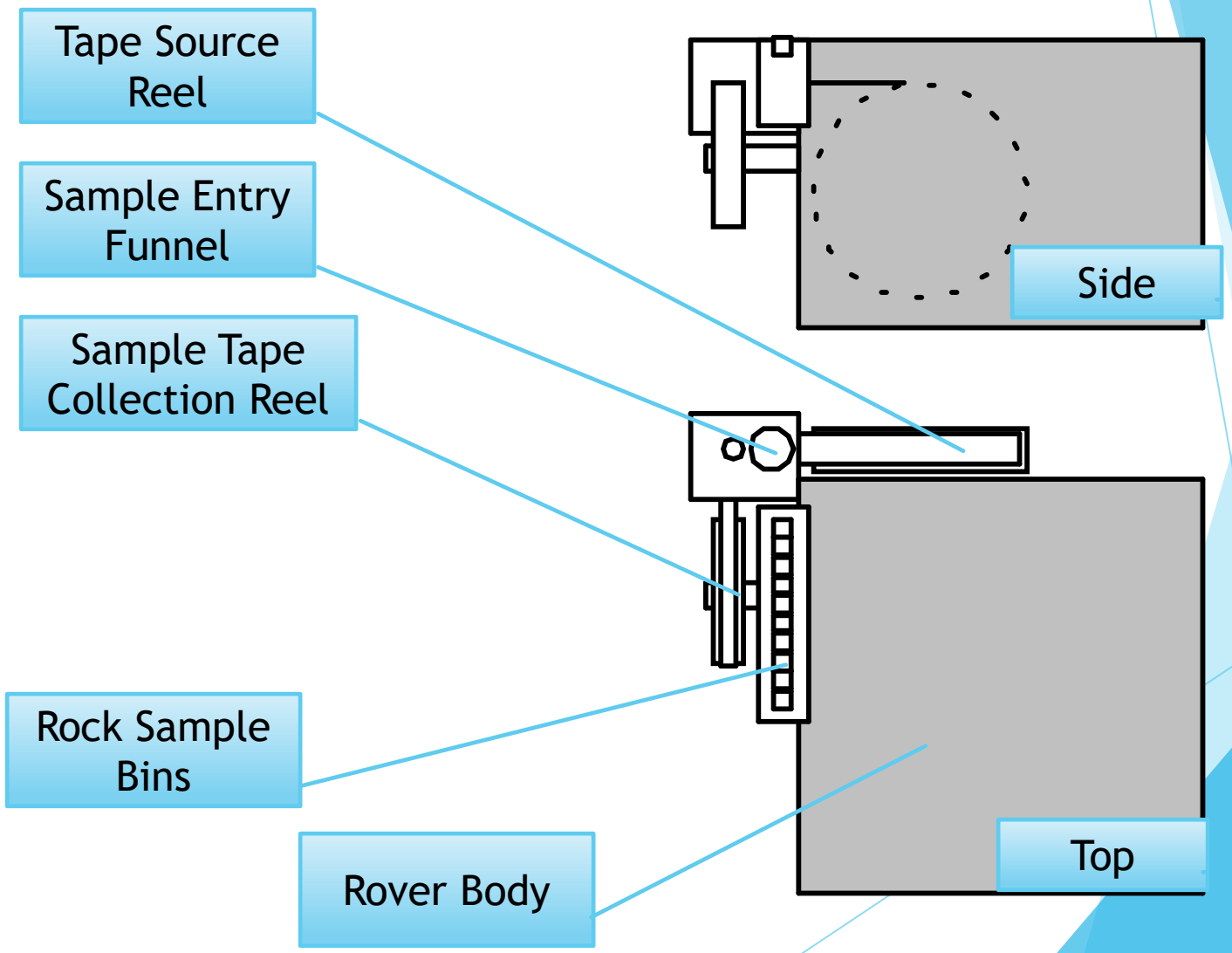




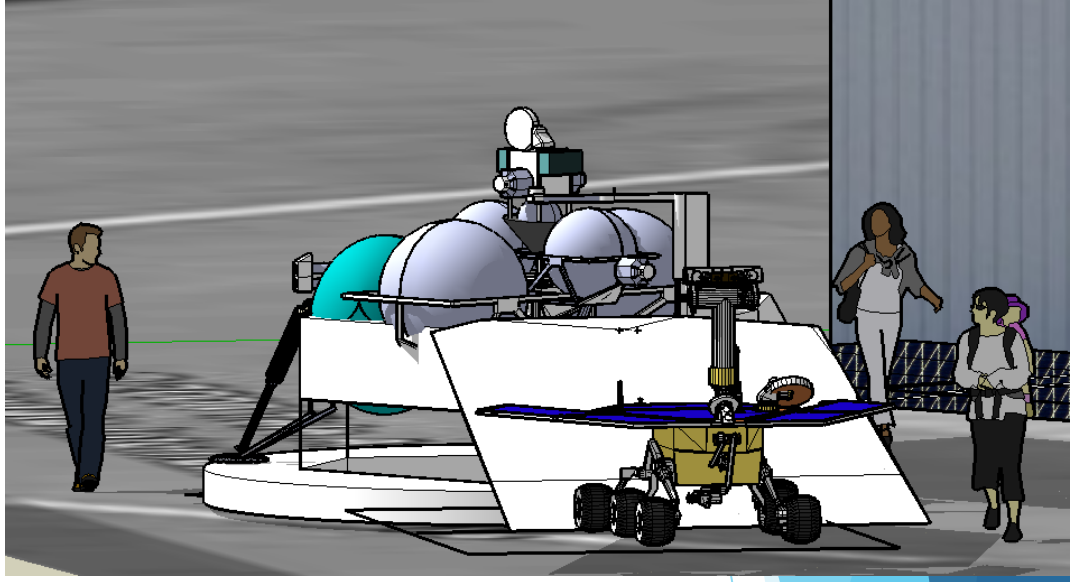
Solar Array Deployment



Rover Sample Storage Device



Moving Forward: Mars Workbench



- Plan to build elements of the vehicle as a competition underway
  - When Mars Society held Project Challenge in 2008, this concept came in second in voting behind TEMPO^3.
  - An independent international team has continued work on Mars Workbench and is seeking partners and sponsorship.
  - Contact Kent Nebergall at knebergall@gmail.com.

Questions?