National Aeronautics and Space Administration

Reduction of Launch Mass with Solar Sail Propulsion

Mars Sample Return Concept Study

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MSFC Advanced Concepts

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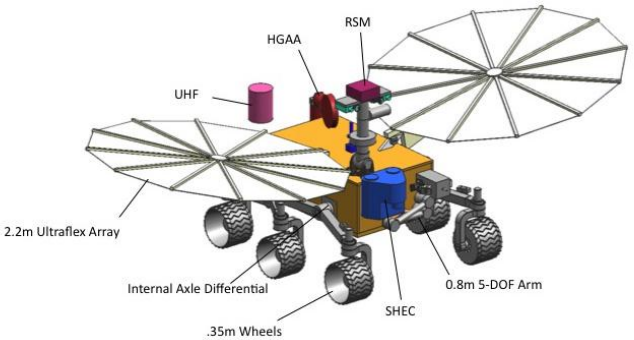
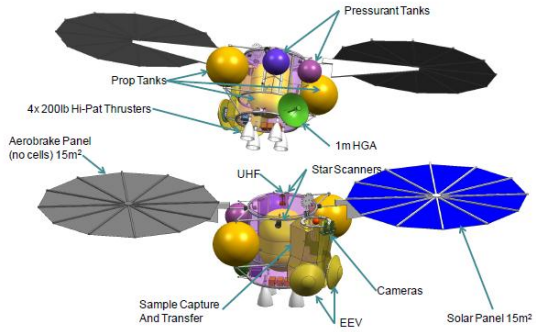
DEPLOYTECH Background

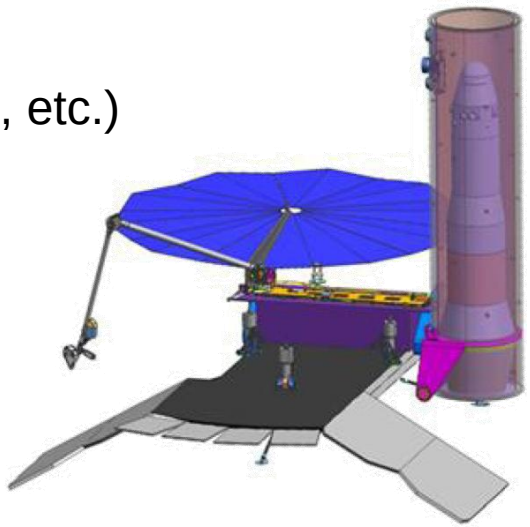
- Three year project awarded to Surrey Space Center by the European Commission
- Three main objectives for the DEPLOYTECH Project
  - Advance technology readiness levels of space deployable technologies
  - Develop updated mathematical models to analyze deployable structures
  - Develop testing methods and facilities for ground based tests of space deployable structures
- Partnership between NASA MSFC and University of Surrey to aid in development of space deployable technologies
  - Principal Investigators: Les Johnson and Vaios Lappas
  - NASA MSFC Engineering Directorate Support

Mission Overview

- Planetary Science Decadal Survey Mission
  - Three ‘separate’ missions to remain under cost caps
    - Astrobiology Explorer (Rover)
    - Sample Return Orbiter (with EEV)
    - Sample Return Lander (with Ascent Stage)
- MSR ERS Modifications
  - Replace Sample Return Orbiter MPS system with solar sail
    - Maintain EEV from Decadal Survey Mission
    - Determine solar sail characteristics (size, mass, etc.)
    - Determine new spacecraft characteristics (size, mass, etc.)



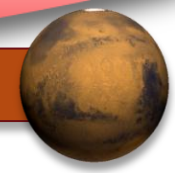




Mission Concept Assumptions

- Repackage the Sample Return Orbiter to minimize mass and redundancy
- Launch with Max-C rover on Atlas V 551 in 2028
- Use solar sail as main interplanetary propulsion system
  - Case 1 – Mars-to-Earth transfer only
  - Case 2 – Earth-to-Mars and Mars-to-Earth
- Limited RCS for course correction and sample rendezvous procedures
- Orbiter and ERS separate at Mars, ERS only returns to Earth with sample

Case 1: Mars-to-Earth Only



Mars

Mars Orbit

Aerocapture into Mars Orbit

Sample Return Orbiter Operations

Rendezvous w/ Orbiting Sample

Orbiter and ERS Separation

Solar Sail Deployment

Orbiter Expended

Mars Spiral Out ~435 days

Mars Transfer ~350 days

Mars-to-Earth Transfer ~507.5 days

TMI

LEO

EEV Separation

TMI Stage Expended

Earth Entry Velocity < 12 km/sec

Expendable Launch Vehicle

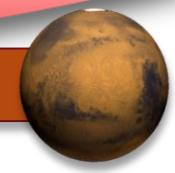
Direct Entry

Total Transit Time = 3.54 years

Earth

Not to scale

Case 2 : Round Trip



Mars Orbit

Mars Arrival

Sample Return Orbiter Operations

Rendezvous w/ Orbiting Sample

Orbiter and ERS Separation

Orbiter Expended

Mars Spiral Out ~435 days

Mars Transfer ~758.5 days

Solar Sail Deployment

Mars-to-Earth Transfer ~507.5 days

TMI

LEO

EEV Separation

TMI Stage Expended

Earth Entry Velocity < 12 km/sec

Expendable Launch Vehicle

Direct Entry

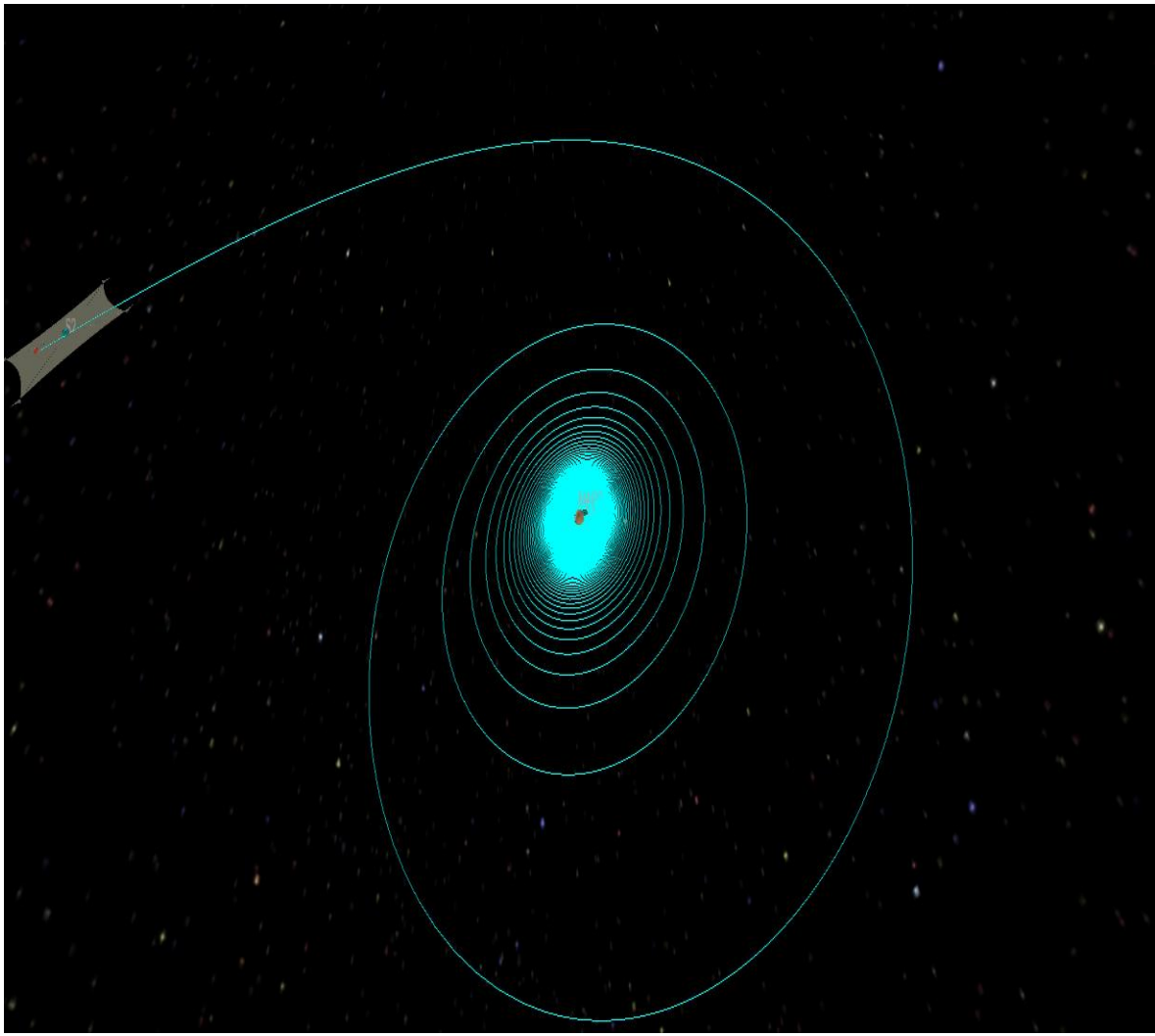
Total Transit Time = 4.66 years

Earth

Not to scale

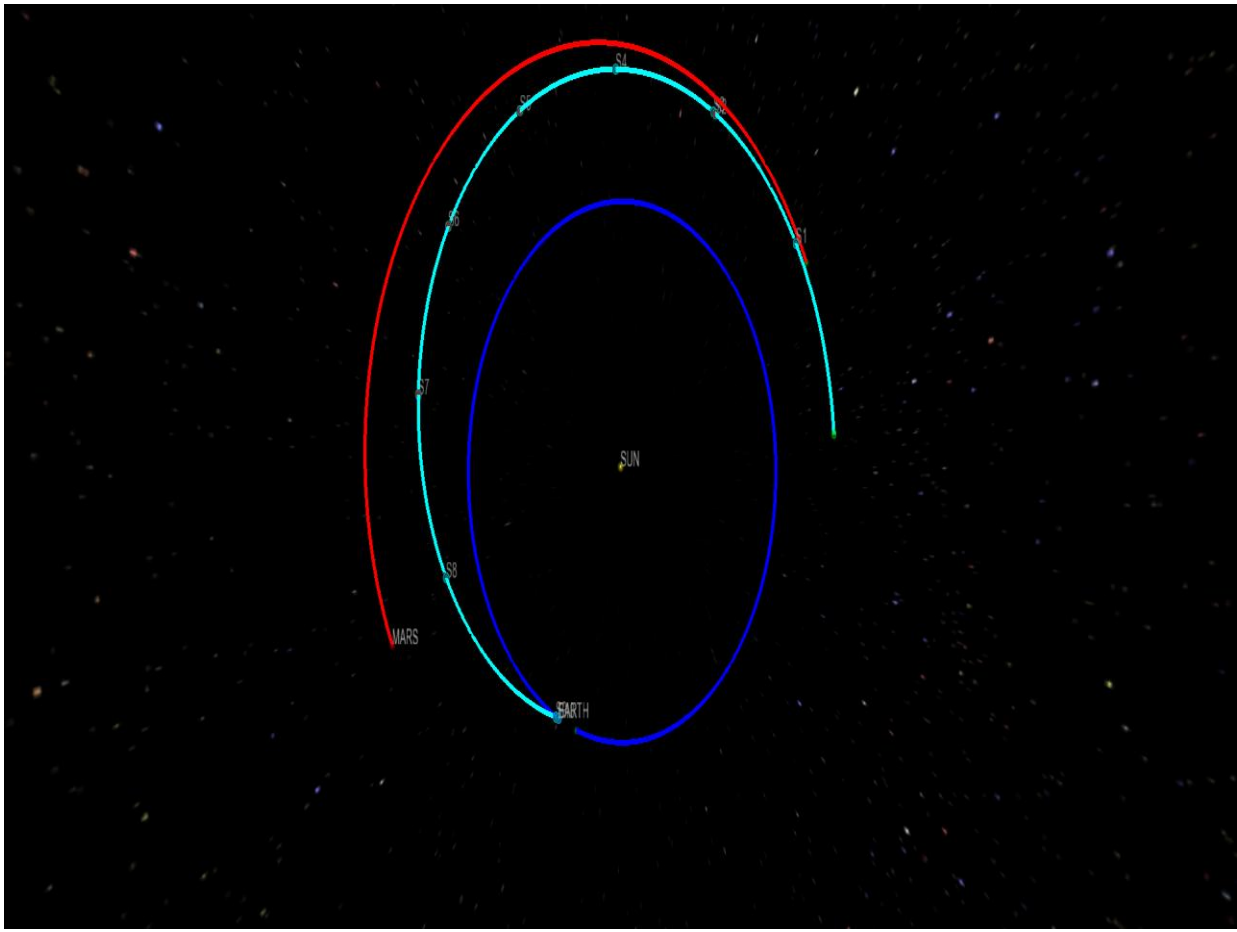
Case 1: Mars Spiral Out

- Assumptions
  - Area = 18,887 m2
  - Payload Mass = 200 kg
  - Sail Mass = 115 kg
  - 2.5 µm CP1
  - Sun Synchronous Orbit
  - Start at 500 km Circular orbit
  - 93.2 inclination
- Characteristic Acceleration = 0.50 mm/s2
- Time of Flight is 435 days



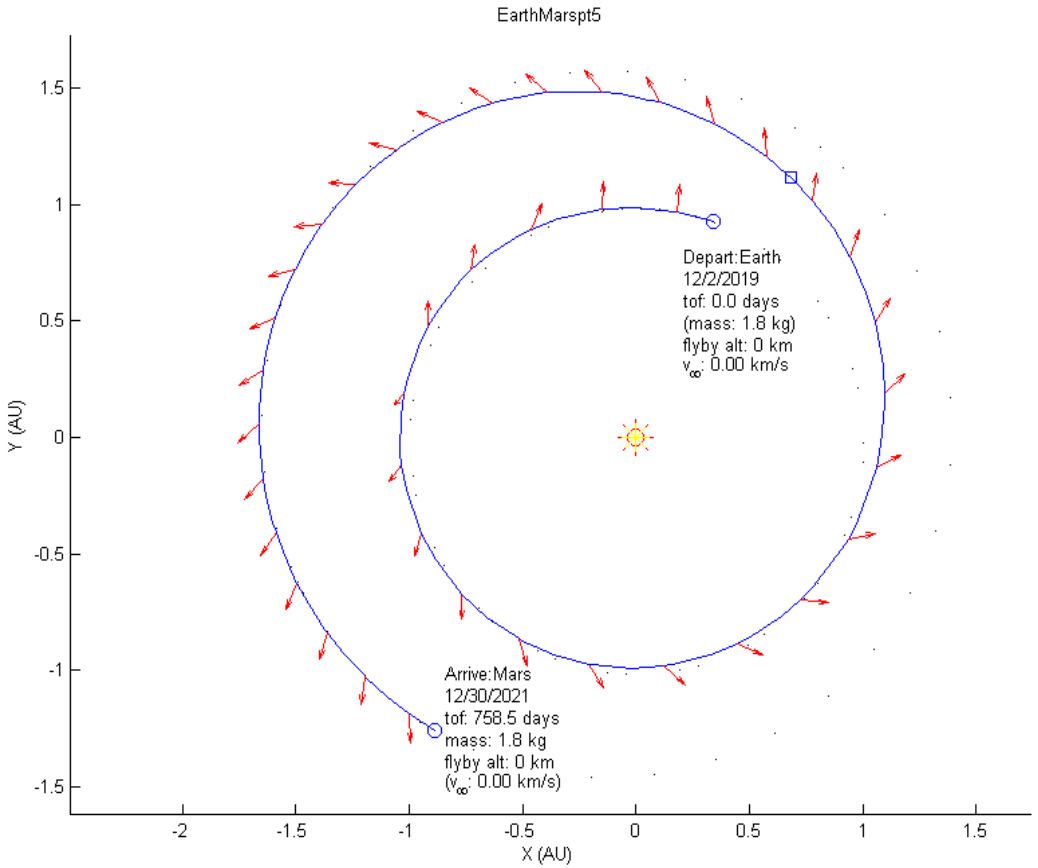
Case 1 & 2: Mars-to-Earth Transfer

- Assumptions
  - Leaving Mars at perihelion
  - Initial orbit Mars orbit
- V_{inf} of arrival of 6.4 km/s2
  - Entry velocity of 12.8 km/s2
- Time of Flight is 507.5 days

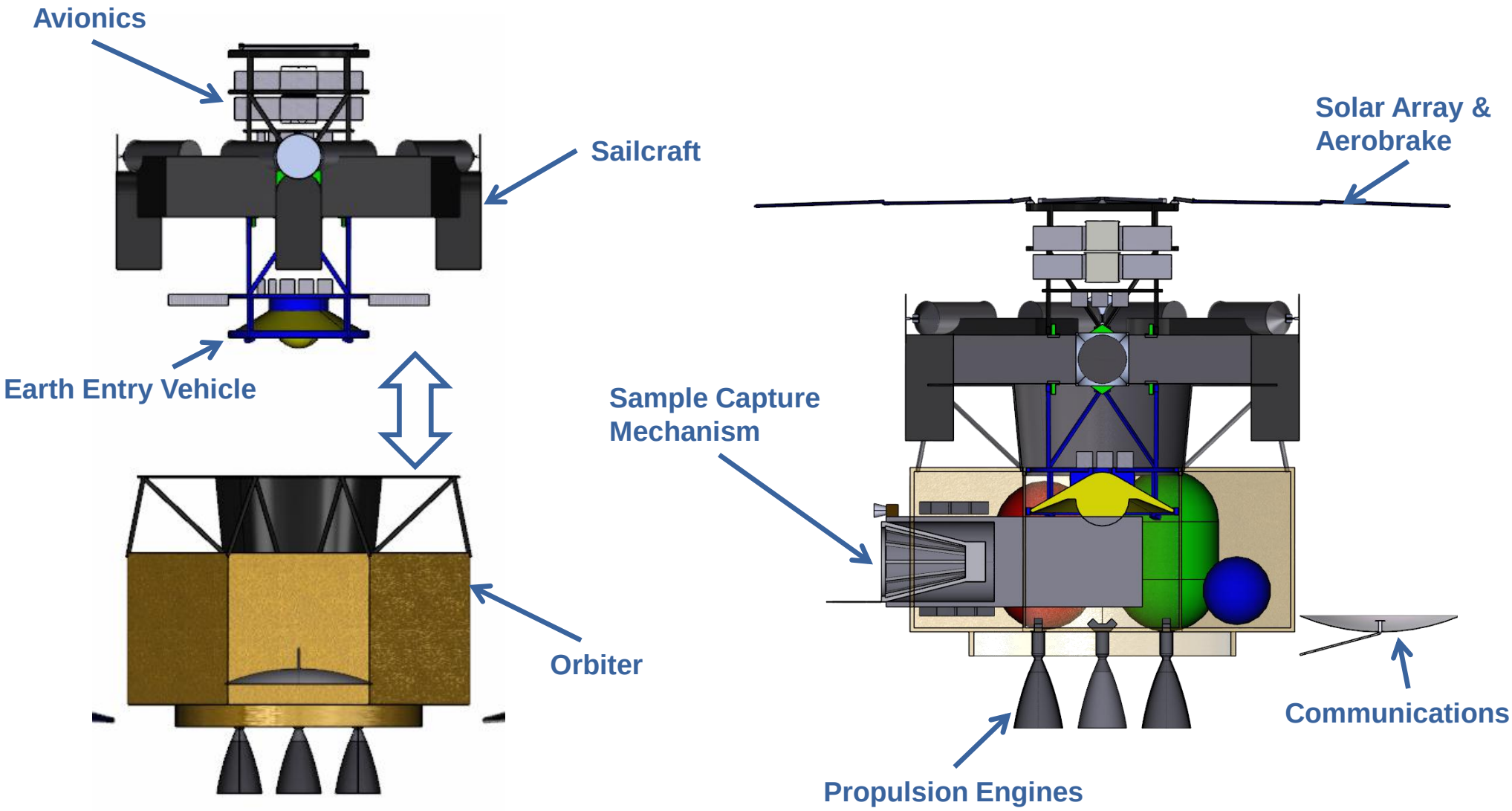


Case 2: Earth-to-Mars Transfer

- Assumptions
  - Leaving Earth with a C3 of zero
  - Sail deployed after TMI burn by launch vehicle
- Characteristic Acceleration = 0.50 mm/s2
- Time of Flight is 758.5 days



Configuration



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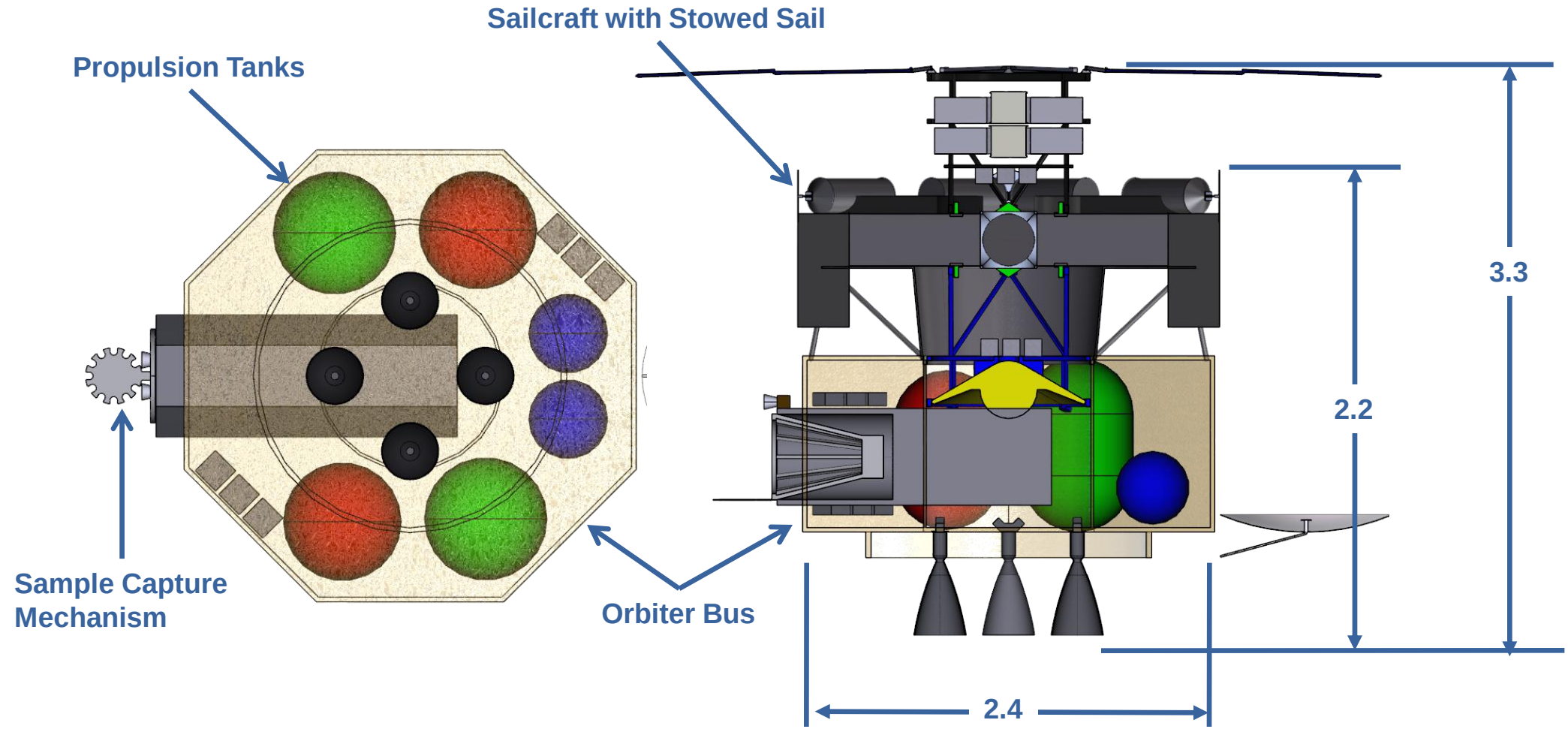
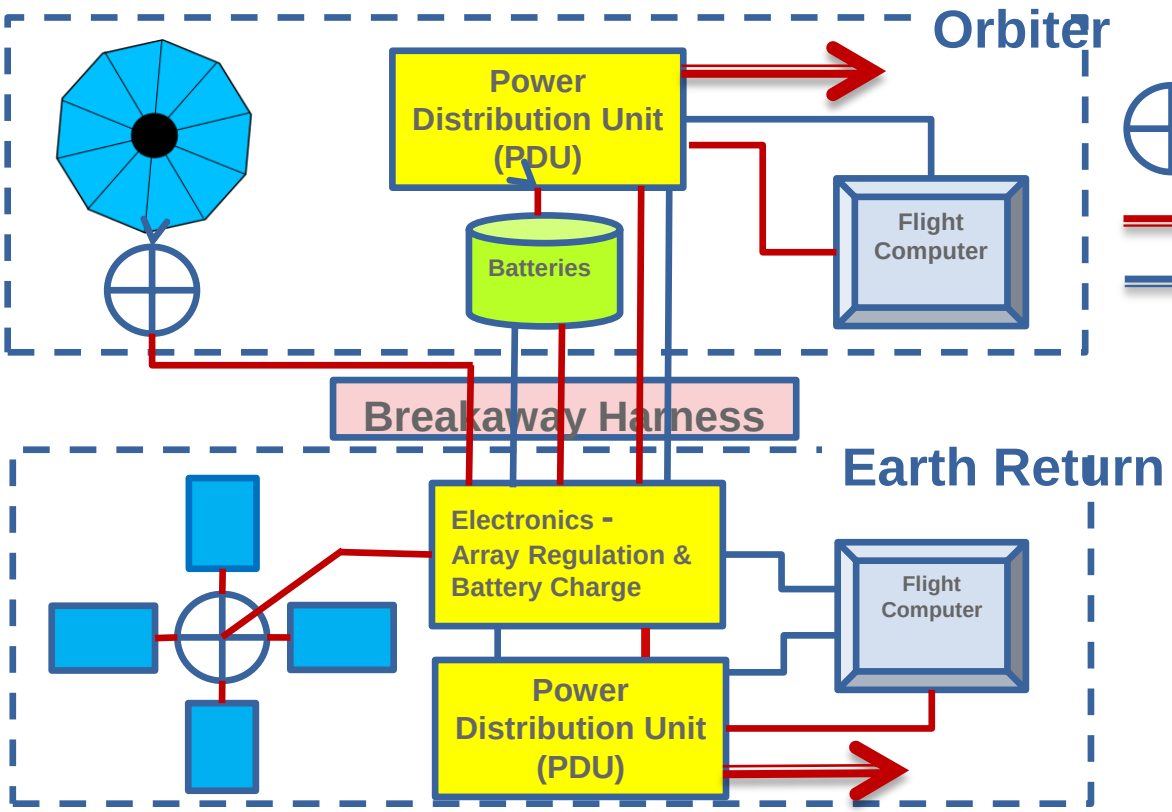
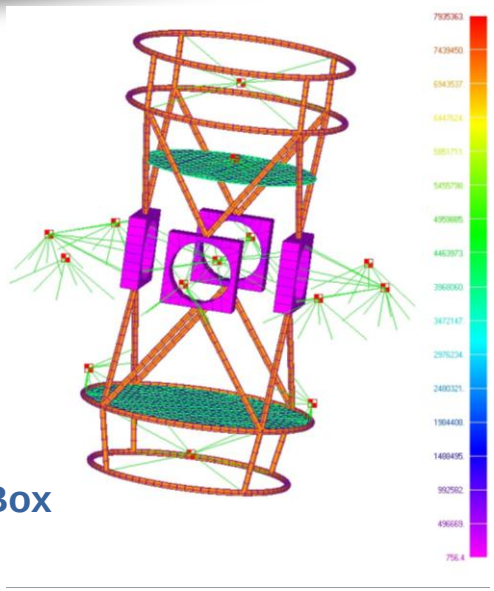
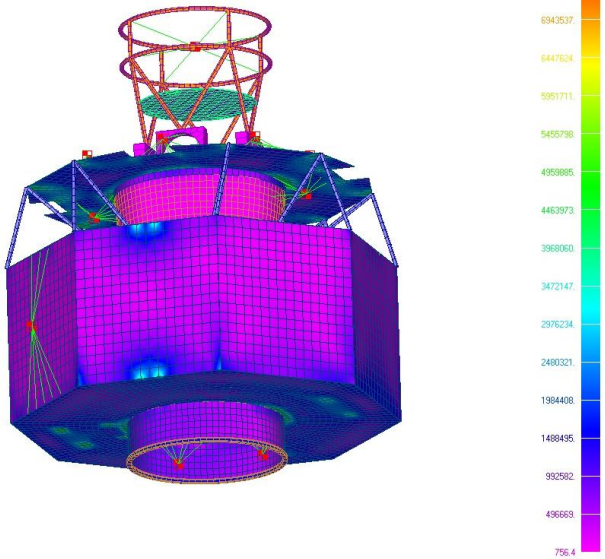


Systems Analysis

- Structures: Finite Element Analysis
- Power: Power Distribution Schematic

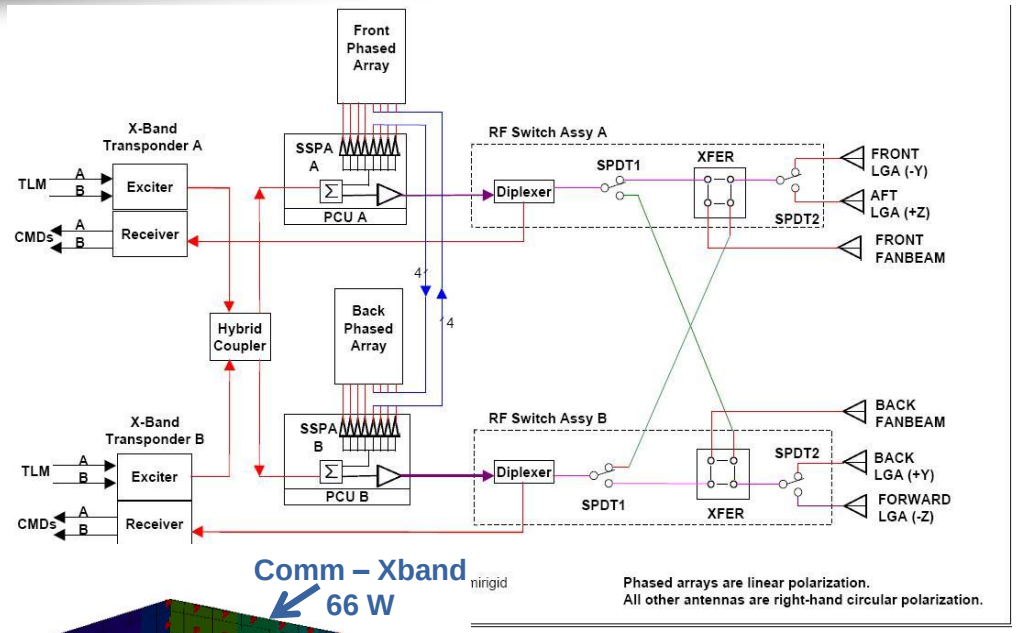


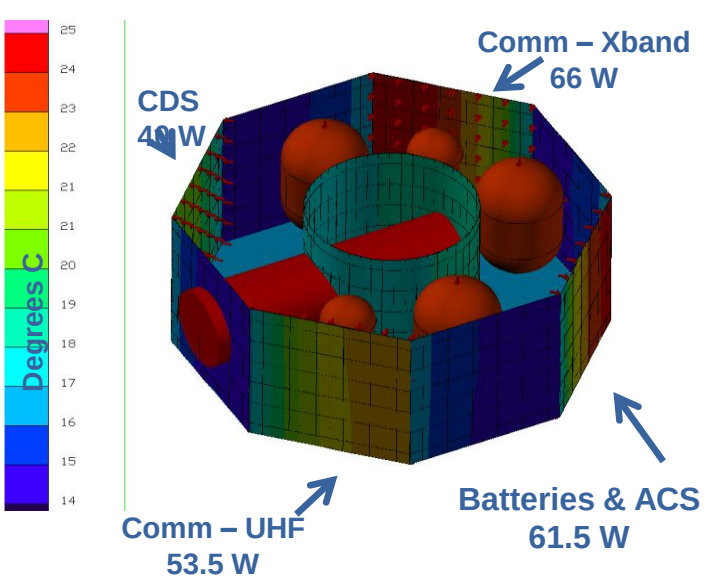


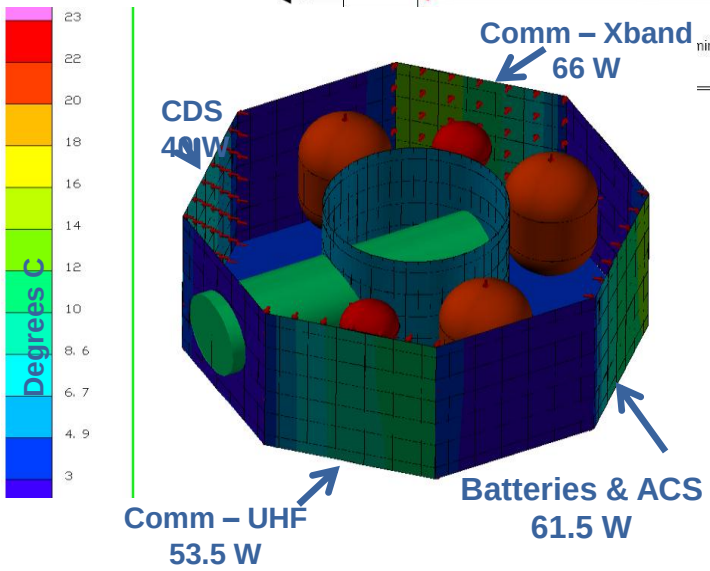


Subsystems Analysis

- Avionics: C&DH Schematic
- Thermal Analysis







Mass Results

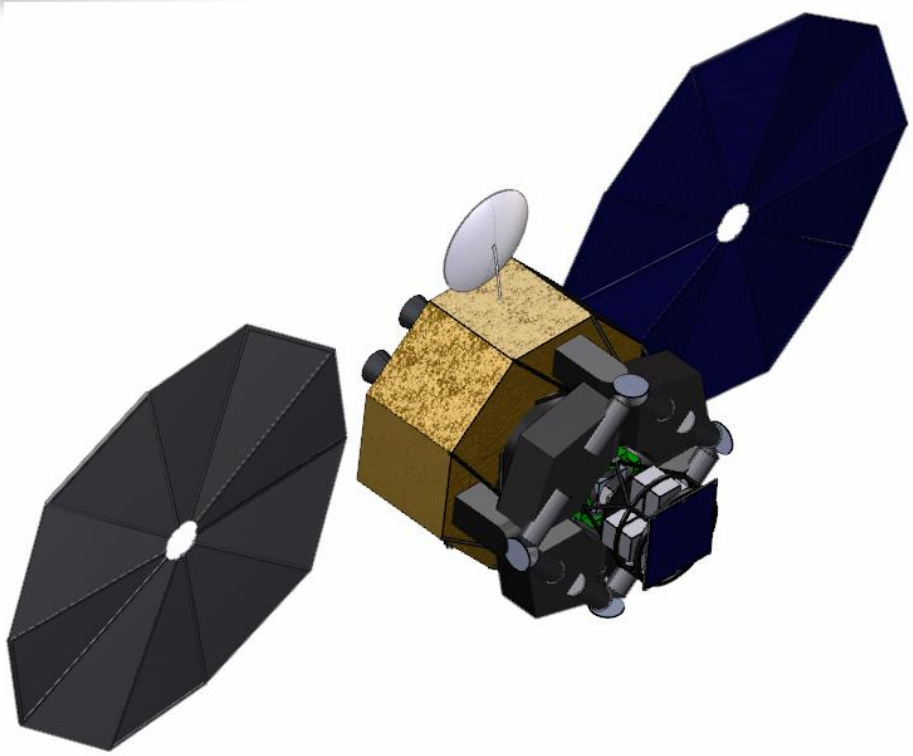
Case 1	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Orb+ERS	1947.5
Total	**5503.3**

Case 2	Predicted Mass (kg)
Max-C Entry System	1550.7
Descent Stage	1313.1
Pallet	327.5
Max-C Rover	364.5
ACO Delta Orb+ERS	508.8
Total	**4064.6**

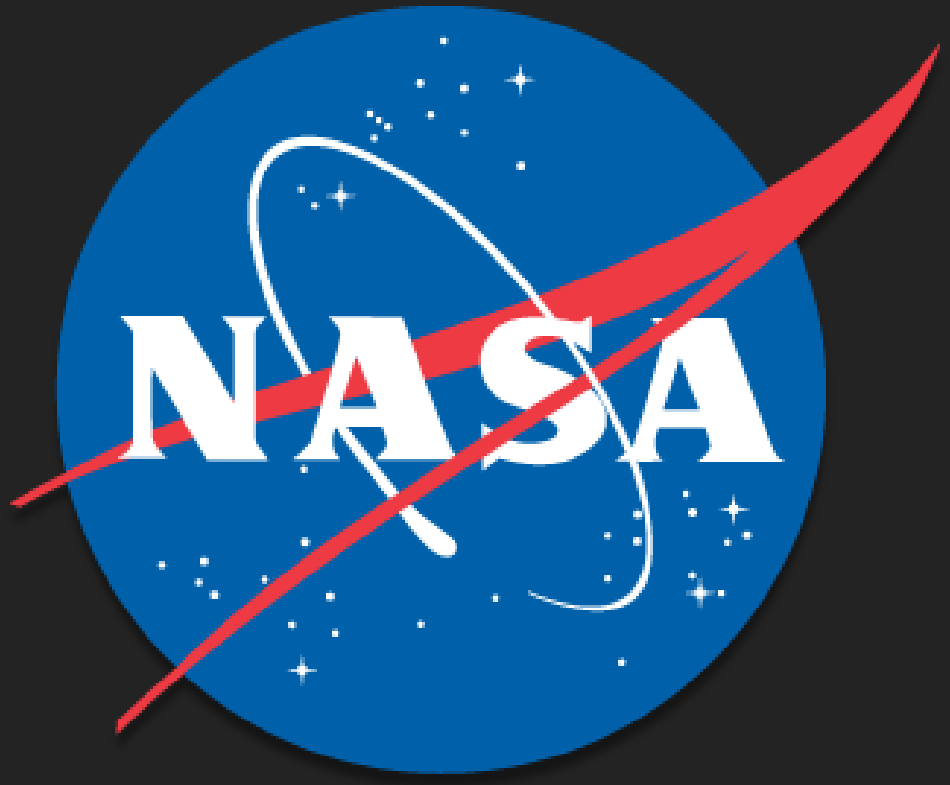
Launch Summary	
2028 Atlas V 551 Mass (kg)	5150
Delta Mass (kg)	4064.6
Launch Contingency:	**21%**

Conclusions

- Presented to the Mars Project for consideration
- Dual launch manifest enabled if a solar sail is utilized on a round trip
- Repackaged the Orbiter and Earth Return System into a configuration that allows stowage and deployment of the 150 M solar sail system



Met all mission requirements and would eliminate one Atlas V launch saving the project time and money!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