MAV

Mars Ascent Vehicle

# Drivers, Developments and Options for a Mars Ascent Vehicle

Robert Shotwell

Chief Engineer Astronomy, Physics and Space Technology

MSFC

Marshall Space Flight Center

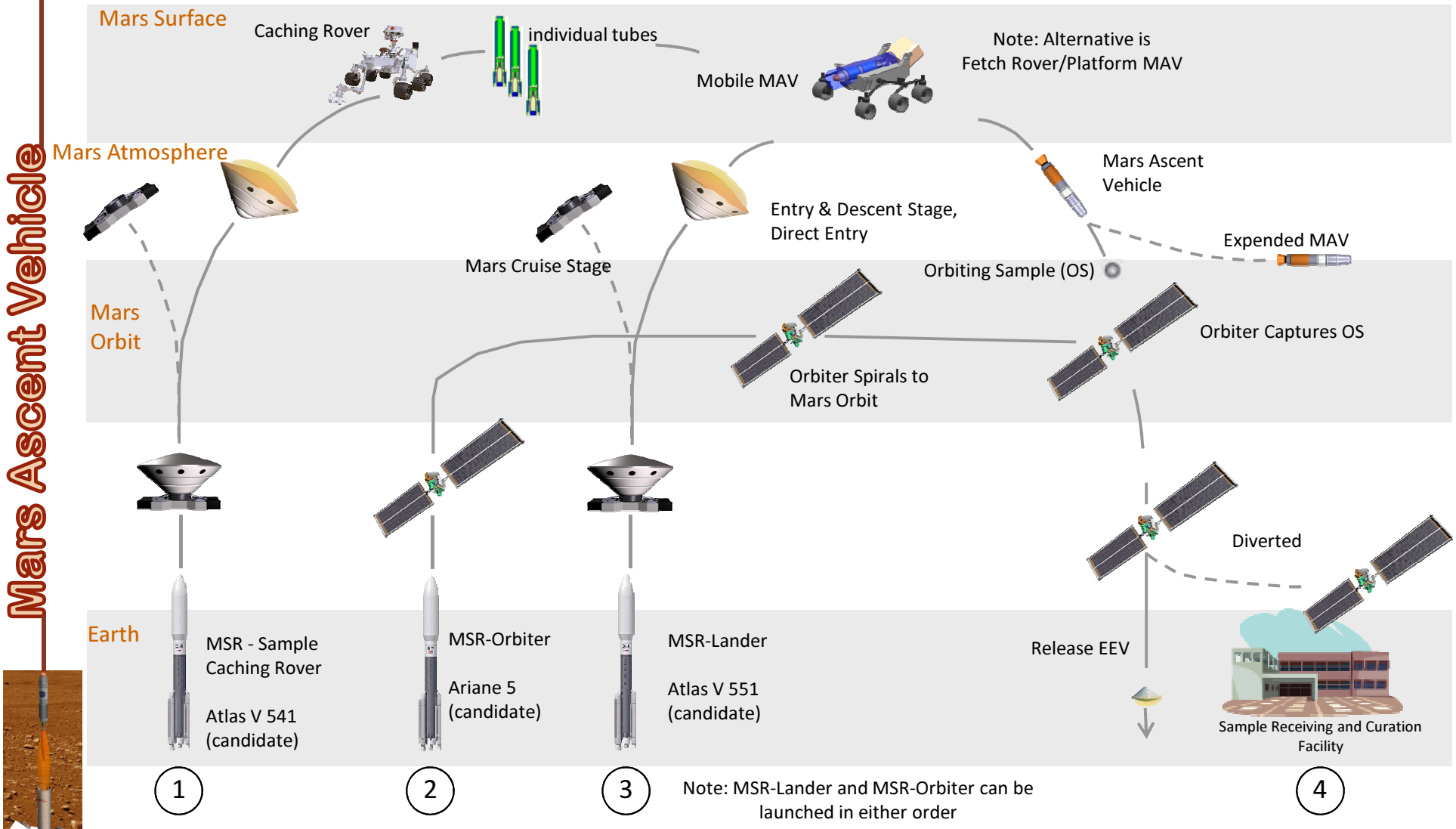
JPL

Jet Propulsion Laboratory

California Institute of Technology

LaRC

# MSR Reference Architecture

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# Orbiting Sample Concepts

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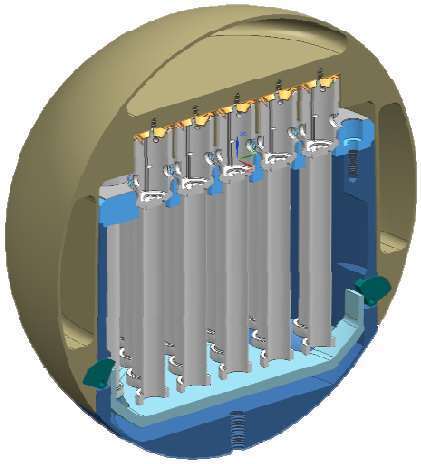
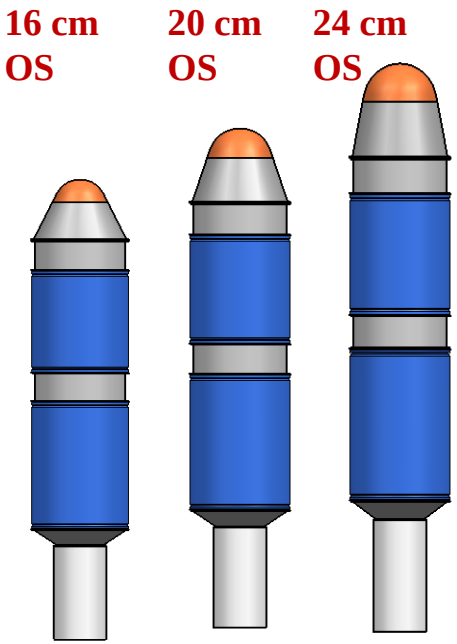
- The Primary Payload for the MAV is the Orbiting Sample (OS)
- The OS is assumed to be mounted to the MAV when it departs from Earth
- As the number and size of samples to be returned grows, the OS grows as well
  - Drives MAV size and mass
- MAV assumes TPS material on forward hemisphere
  - No Fairing

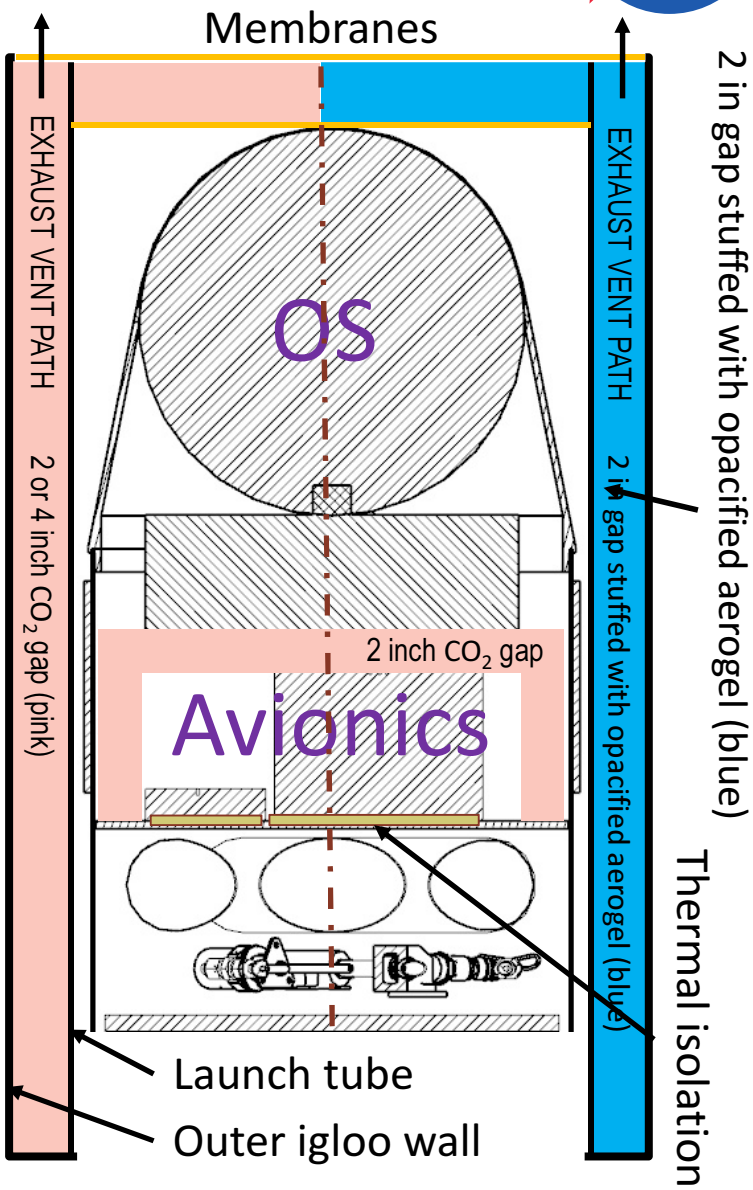




# MAV Thermal Accommodation Needs

Mars Ascent Vehicle

- Two thermal control zones:
  - Avionics bay (-40 C mission duration)
  - Entire MAV (pre launch warmup)
- Martian $CO_2$ gap provides insulation
- Thermal study suggested required radial gap for current MAVs
  - 2 in gap around MAV avionics hardware
  - 4 in radial gap for “warm” MAV
    - Solid, liquid-liquid biprop
  - 2 in radial gap for “cold” MAV
    - Hybrid, frozen MAV
- Opacified aerogel cuts gas gap in half
  - Adds integration complexity, not recommended for rover itself
  - Baseline approach for igloo design
  - May complicate exhaust venting
- Thermal loop from potential RTG to launch tube
  - Would require 2 inch $CO_2$ gap



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# Critical Event Comm and Tracking

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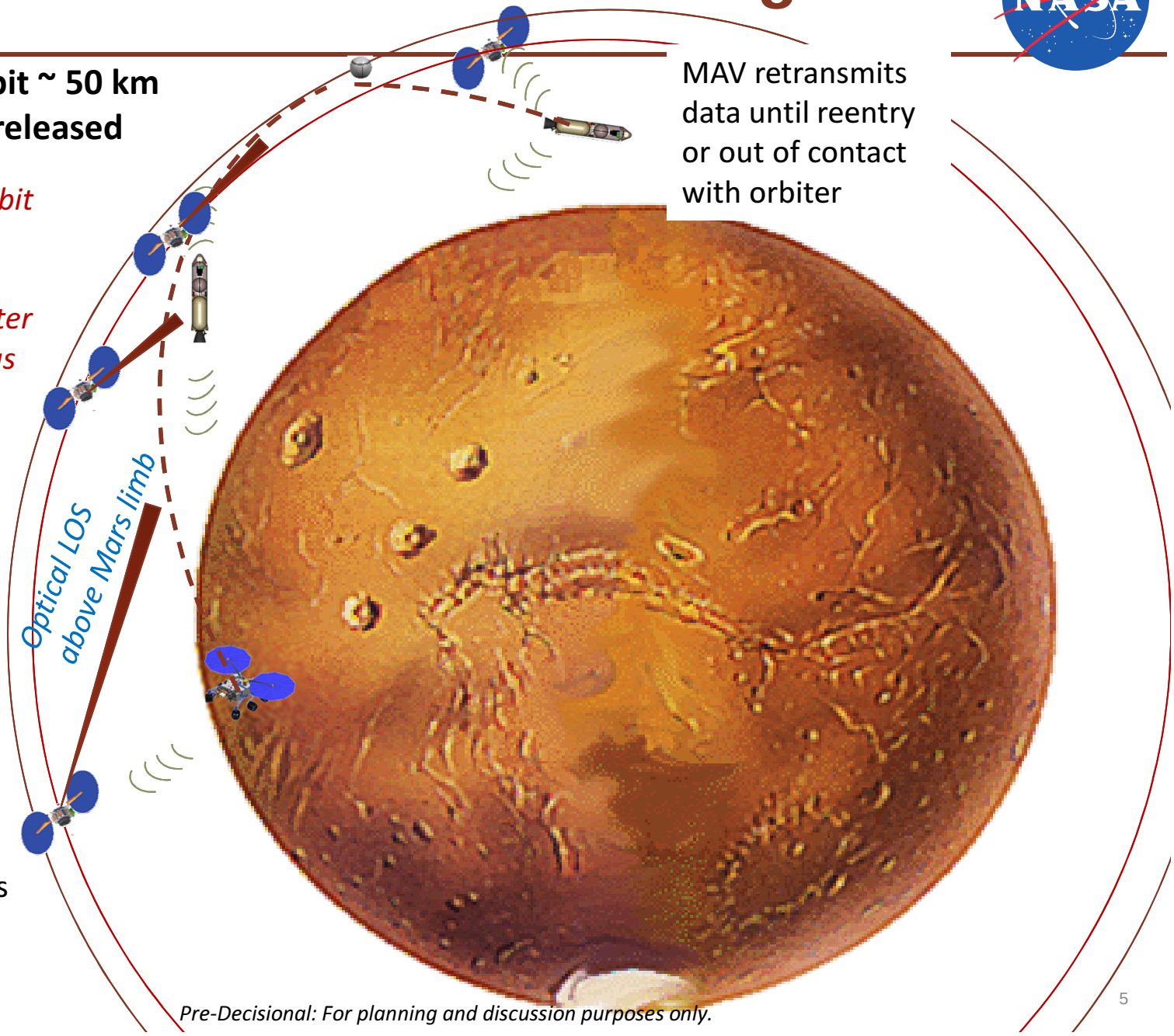
**MAV reaches orbit ~ 50 km ABOVE SRO, OS released**

*MAV provides orbit ephemeris data through orbiter comms, but orbiter tracks optically as well as backup method*

Comms to lander and SRO (plus other assets if available) during flight

Orbiter at T0 (launch), status green, comms verified




MAV retransmits data until reentry or out of contact with orbiter

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# Open Trades

*Green indicates current prevailing preference

- Lander Trades
  - **Mobile** vs Platform
    - Affects packaging volume and mass
  - **RTG** vs Solar
    - Affects MAV thermal limits and lander power /energy reqs
- Mission Trades
  - Landing site and target altitude (will be chosen by Science for M2020 @2019)
  - Size of payload (will be driven by M2020 tube design and additional reqs assigned to OS)
- MAV trades
  - Type of prop to use (solids, **hybrids**, liquids)
  - RCS approach (**cold gas**, warm gas, passive stabilization, mixed)
  - Internal redundancy (single string vs **selected redundancy** vs block)
  - Staged vs **SSTO**
  - Faired or **direct payload**
  - Vertical vs **inclined launch**

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# FY 14 Comparison of Systems

Mars Ascent Vehicle

6.65kg Payload, 20cm Reference OS

| | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 | Case 7 | Case 8 | Case 9 | Case 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Solid-Solid G-G | Solid-Solid G-U | Solid-Liquid G-G | SSTO Monoprop | SSTO Pump BiProp | SSTO Reg. BiProp | SSTO Hybrid | Hyb-Hyb G-G | Hyb-Solid G-G | BiProp-BiProp G-G |
| | | | | | | | | | | |
| Score | 0.60 | 0.54 | 0.32 | 0.52 | 0.79 | 0.76 | 0.76 | 0.621 | 0.52 | 0.57 |
| GLOM | 176 | 158 | 237 | 276 | 182 | 187 | 166 | 173 | 157 | 190 |
| Length | 1.88 m | 1.98 m | 2.09 m | 2.76 m | 2.04m | 2.29 m | 2.16 m | 2.78 m | 2.21 m | 2.84 m |
| AFT | -40 C | -40 C | +17 C | +8 C | -37 C | -37 C | -66 C | -66 C | -40 C | -37 C |

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# Comparison of Systems

Mars Ascent Vehicle

6.65kg Payload, 20cm Reference OS

| | Case 1 | Case 2 | | | Case 5 | Case 6 | Case 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Solid-Solid G-G | Solid-Solid G-U | | | SSTO Pump BiProp | SSTO Reg. BiProp | SSTO Hybrid | | | |
| | | | | | | | | | | |
| Score | 0.60 | 0.54 | | | 0.79 | 0.76 | 0.76 | | | |
| GLOM | 176 | 158 | | | 182 | 187 | 166 | | | |
| Length | 1.88 m | 1.98 m | | | 2.04m | 2.29 m | 2.16 m | | | |
| AFT | -40 C | -40 C | | | -37 C | -37 C | -66 C | | | |

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# Current Options Under Consideration

**14kg Payload, 30cm Reference OS**

Mars Ascent Vehicle

| | Case 1a | Case 1b | Case 2a | Case 2b | Case 5 | Case 6 | Case 7 |
|---|---|---|---|---|---|---|---|
| | Solid-Solid G-G | Fixed Solid-Solid G-G | Solid-Solid G-U | Fixed Solid-Solid G-U | SSTO Pump BiProp | SSTO Reg. BiProp | SSTO Hybrid |
| | | | | | | | |
| Max OS | **OS can grow up to ~ 30 cm diameter without fairing (stay under max case diameter)** | | | | | | |
| GLOM | 318.8 | 341.5 | 274.1 | 297.1 | 255.0 | 269.8 | 219.1 |
| Length | 2.64 m | 2.96 m | 2.51 m | 2.87 m | 3.21 m | 3.39 m | 2.89 m |
| AFT | -58 C | -58 C | -58 C | -58 C | -90/-44 C | -90/-44 C | -90/-66 C |

**(Temp limit if frozen, temp limit if not frozen)**

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# Baseline Configurations

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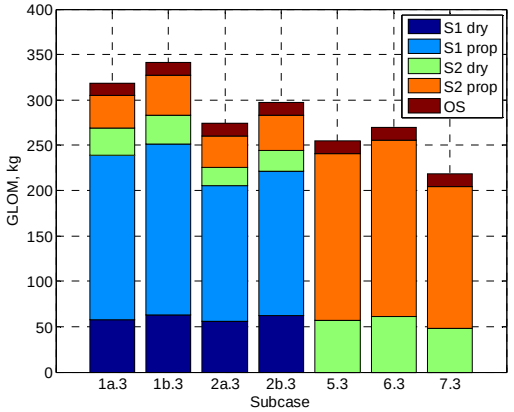
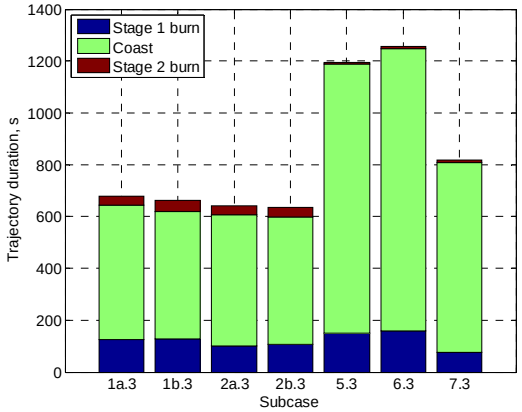
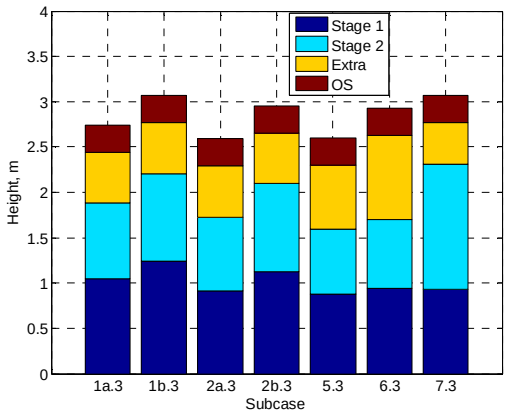
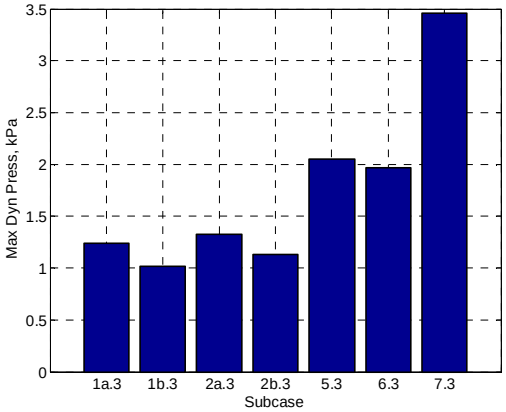
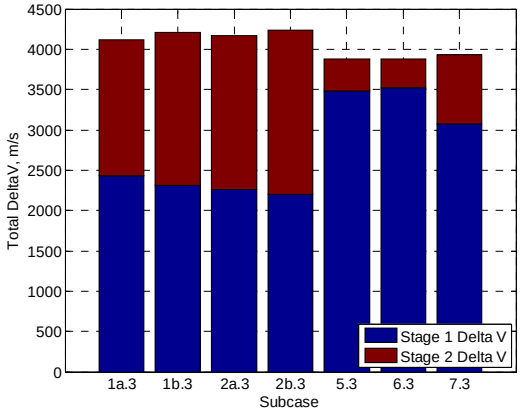
- Lower GLOM for SSTOs
  - Higher mass fraction and Isp
  - Longer, shallower trajectories
  - More efficient trajectory, small burn 2, lower total propulsive $\Delta V$
- Case 7 has higher Isp vs. liquids (320 vs 312 s)
- Case 7 has a larger T/GLOM
  - ~25 N/kg vs. ~15 N/kg of the rest
  - Case 7 larger thrust; burn times are shorter
  - Higher dynamic pressure (also at MECO)
- GLOM and stack height correlate well, except for case 7

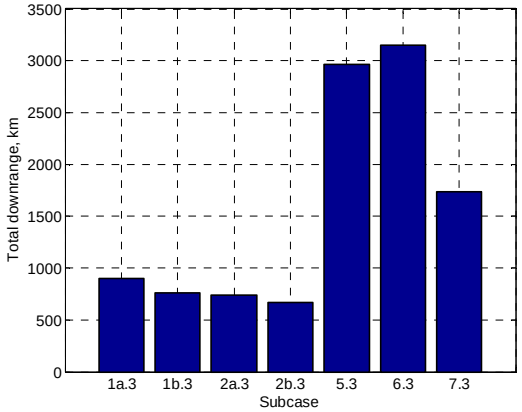
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# Baseline Configurations

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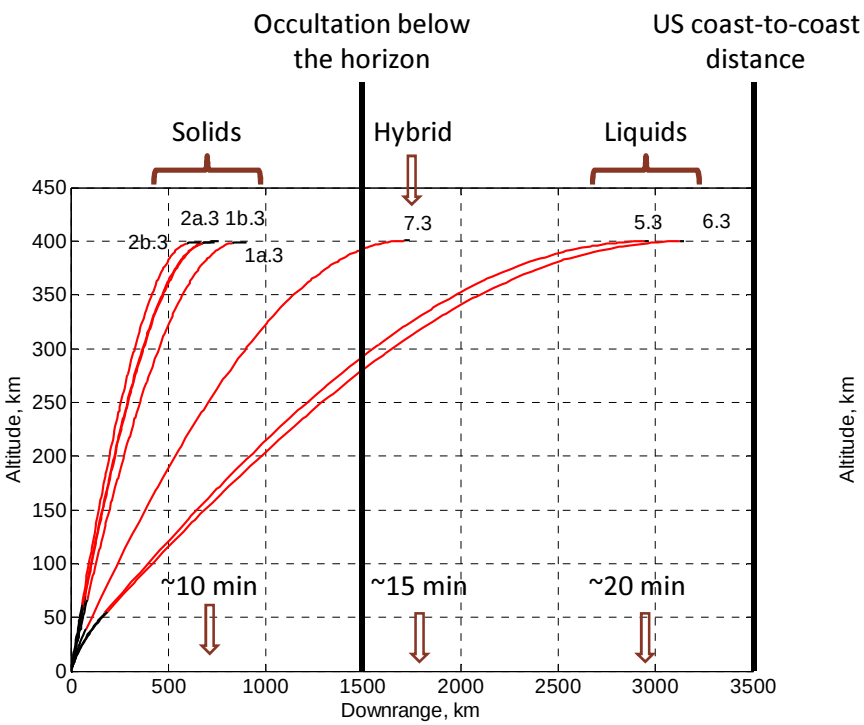
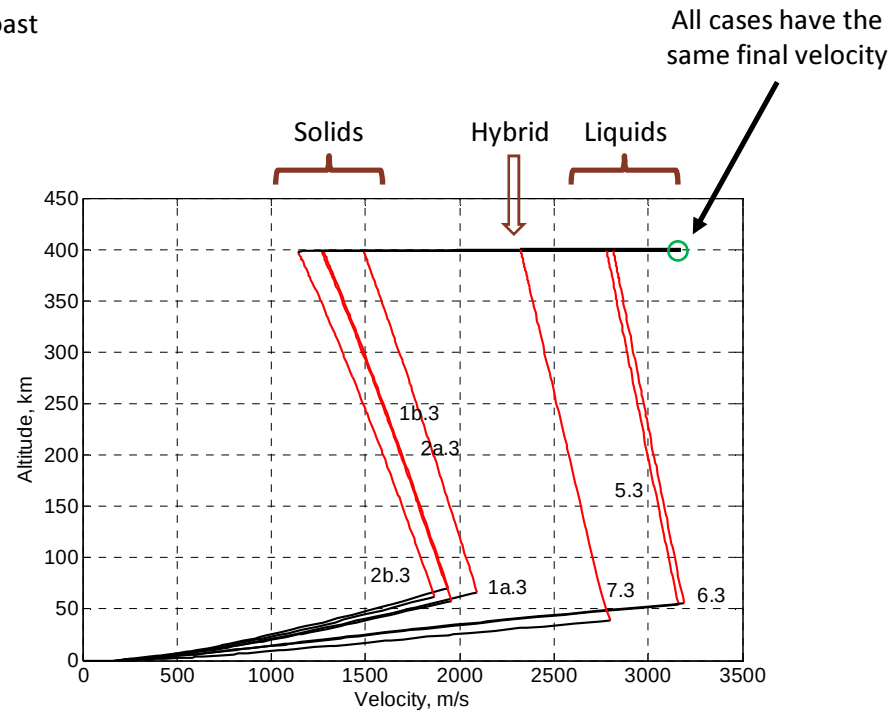
- Strong differences in trajectory profiles for SSTO vs TSTO designs
- Hybrid falls in between due to higher Isp and higher thrust (similar PMF to cases 5 and 6)
- Higher thrust makes the dynamic pressure constraint active, forcing a more vertical trajectory
- Solids burn out higher in the atmosphere, with lower velocity, presenting lower dynamic pressure (comparable T/W, except for case 7)
- Shallow FPA at MECO for liquids (~10 deg) vs. solids (~40 deg)
- Liquids and hybrid are more exposed to atmospheric variability



# Parametric Assessment Results

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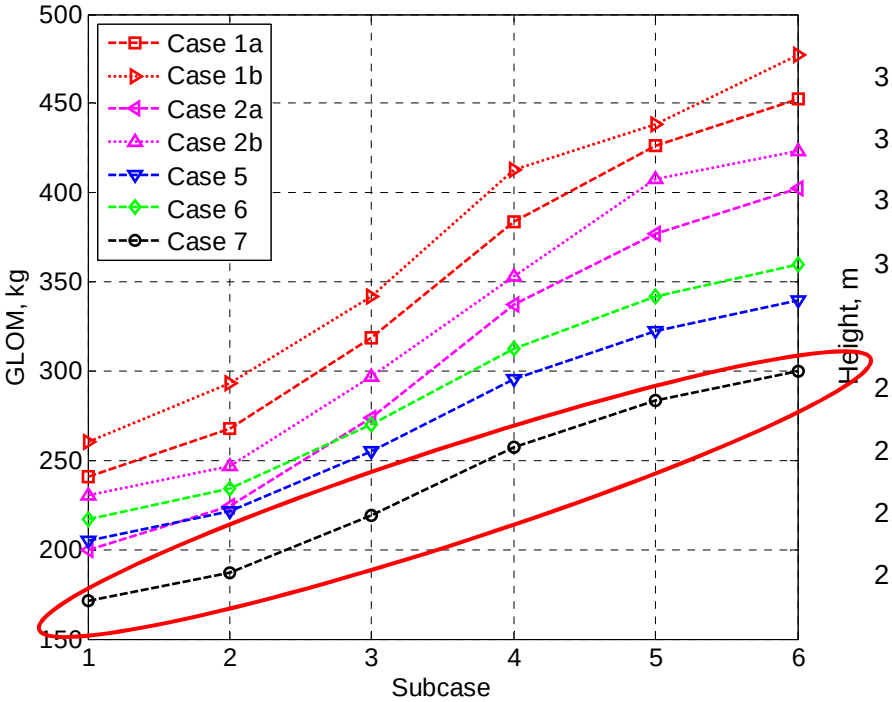
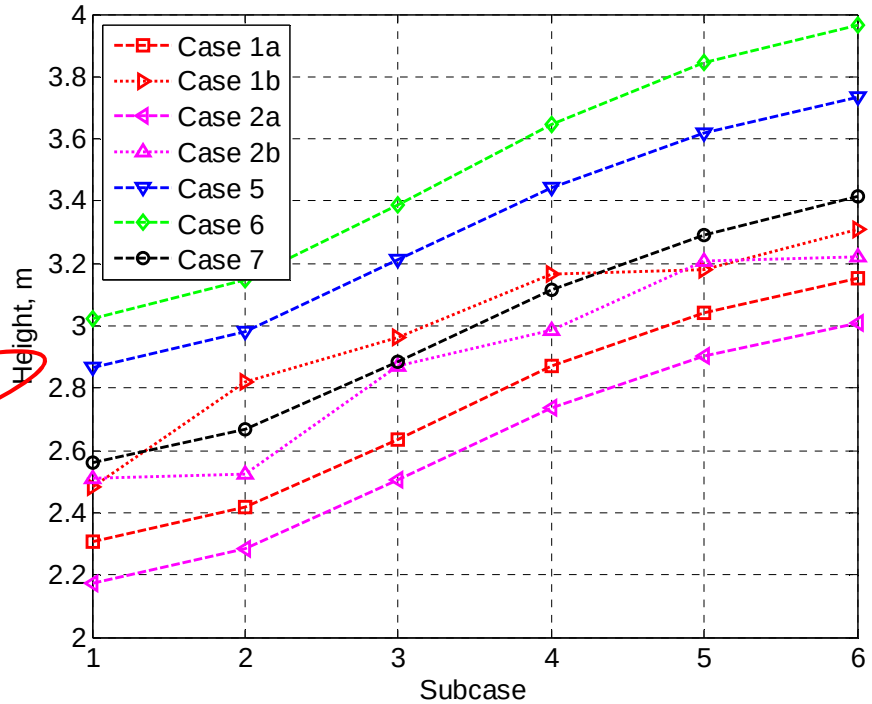
- GLOM
  - Similar trends for all cases, with the TSTO solids presenting the steeper slope
- Stack height
  - Cases 5-6 (liquids) presents the highest stack throughout
  - Cases 1b and 2b have a 'noisy' height profile due to the discrete stage height values

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# Case 7.3 – Pressure Fed Hybrid Motor

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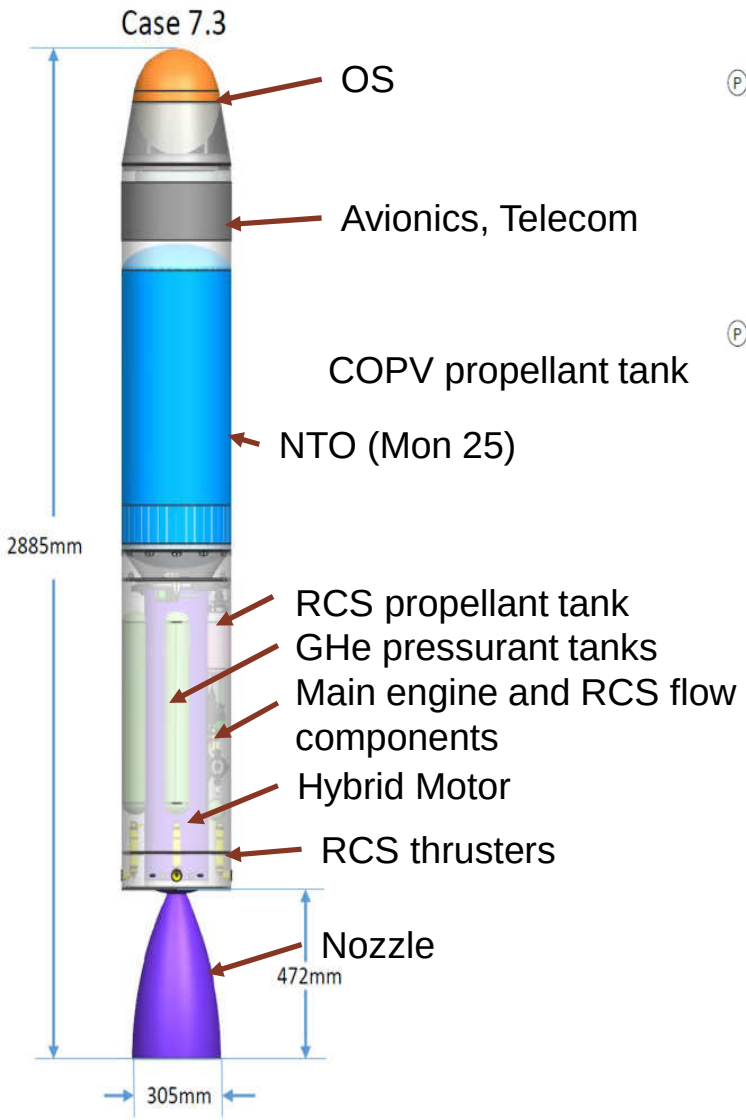


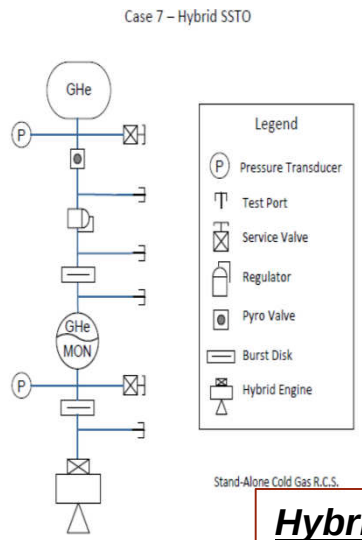


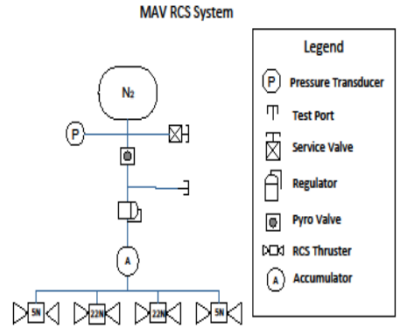


***Hybrid MAV:***

Paraffin and MON25 hybrid motor
GN2 storage pressure: 10 kpsia
Thrust: 5800 N
O/F: 4.56:1
Length: 2.885 m
GLOM: 219.1 kg

Separate RCS operates at 1250 psia

- Currently: 4 thrusters @ 22N and 4 thrusters @ 5 N
- Potential to reduce to 6 thrusters @ 10N

# 3 Phases of Hybrid MAV Development

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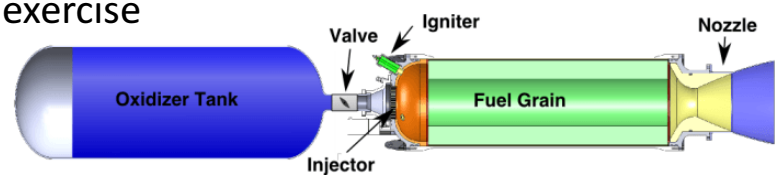
- First phase focuses on hybrid motor design essentials and establishes key performance parameters
  - Testing 3” up to full scale ~10” motor size
  - Establish injector performance and nozzle erosion and lifetime
  - Testing in ground chambers with heavy steel casing and shorter duration burn times
- Second phase takes data learned from development motor tests and builds flight size and weight motors
  - Flight like injectors, wound motor casing, COPV oxidizer tanks, flight weight nozzle
  - Motors ground tested to anchor performance and establish margins
    - Tweak operating points as needed for maximum performance
  - LITVC testing incorporated
- Third phase takes final flight weight propulsion system and incorporates into an airframe for full flight test
  - Demonstrate operation in a free-free condition and exercise all key aspects of a MAV flight profile



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