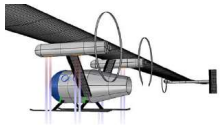
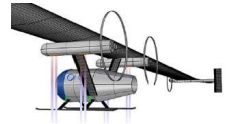


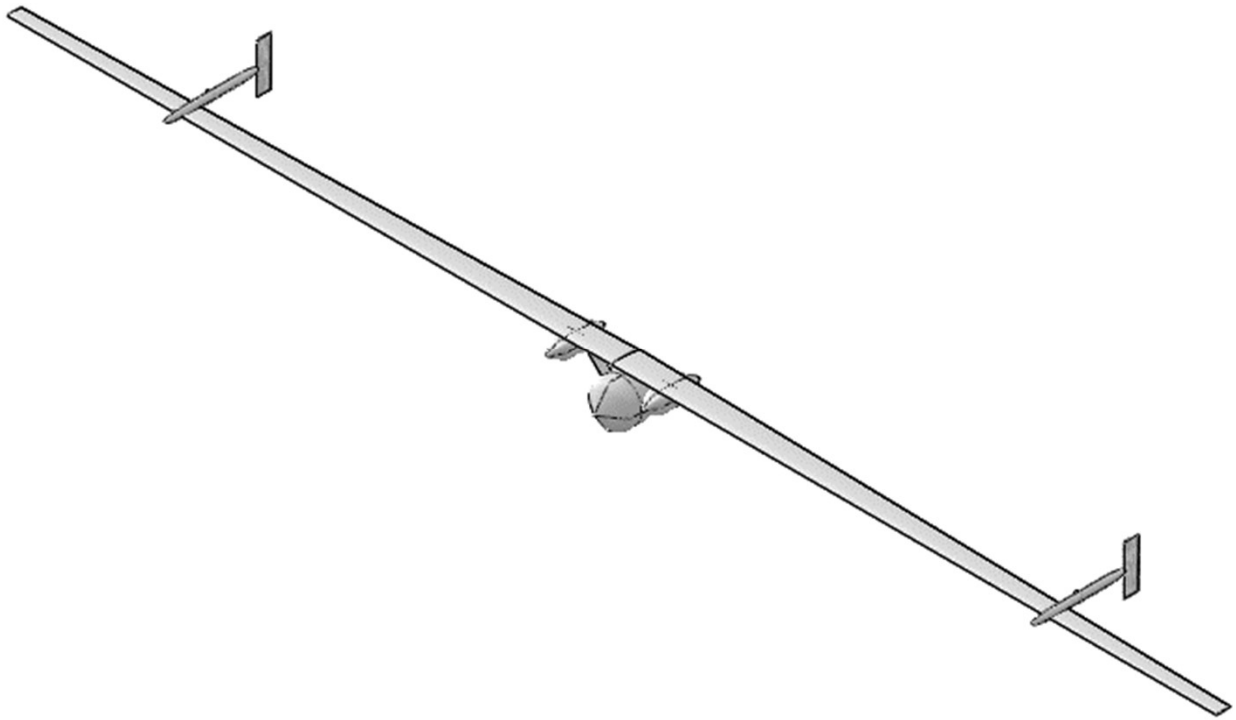
Raymers Manned Mars Plane

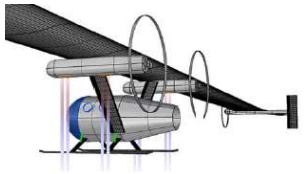
Name: Ramlingam Gyanasampath Pillai
Task: Stability and Control Analysis



Raymers Manned Mars Plane

Control Surface for Stability & Control Analysis

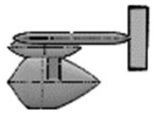




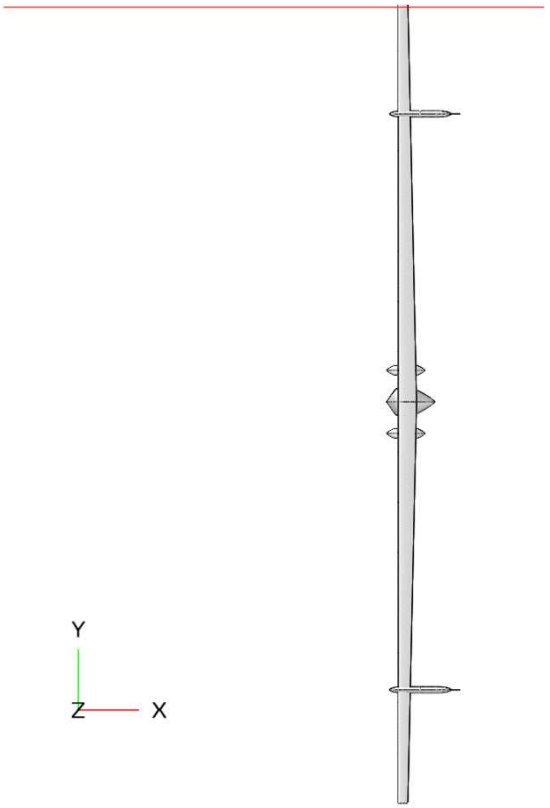
Raymers Manned Mars Plane

Three- View Diagram

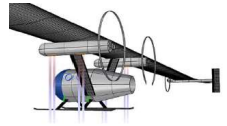
Front View



Side View



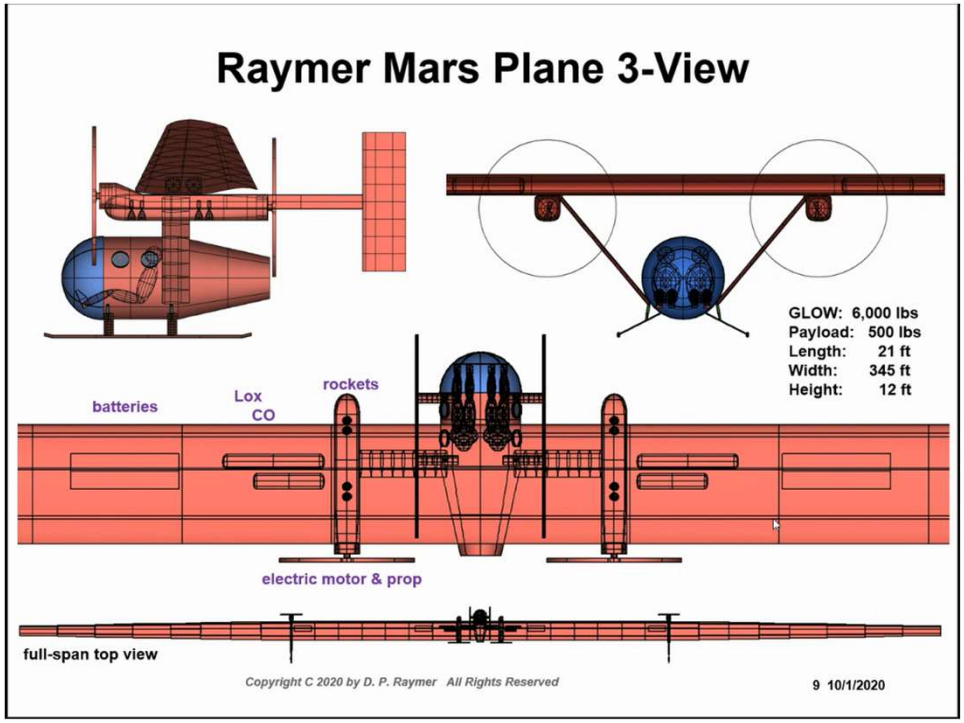
Top View



Raymers Manned Mars Plane

Geometric Parameters

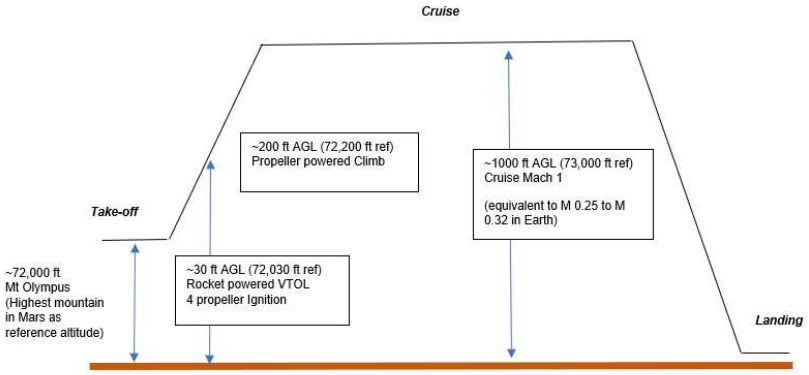
- **The Raymers Manned Mars Plane is a High-Altitude Long Endurance (HALE) aircraft.**
- **The aircraft long span wing, twin boom aircraft carrying two persons and other equipment required for Martian surface exploration.**
- **The Raymers Manned Mars Plane or RMMP aircraft has a twin vertical located at the twin boom separated with each other across the span.**
- **The Version 2 of the RMMP model has Horizontal tail located at the Twin Boom to improve the Longitudinal stability of the aircraft.**

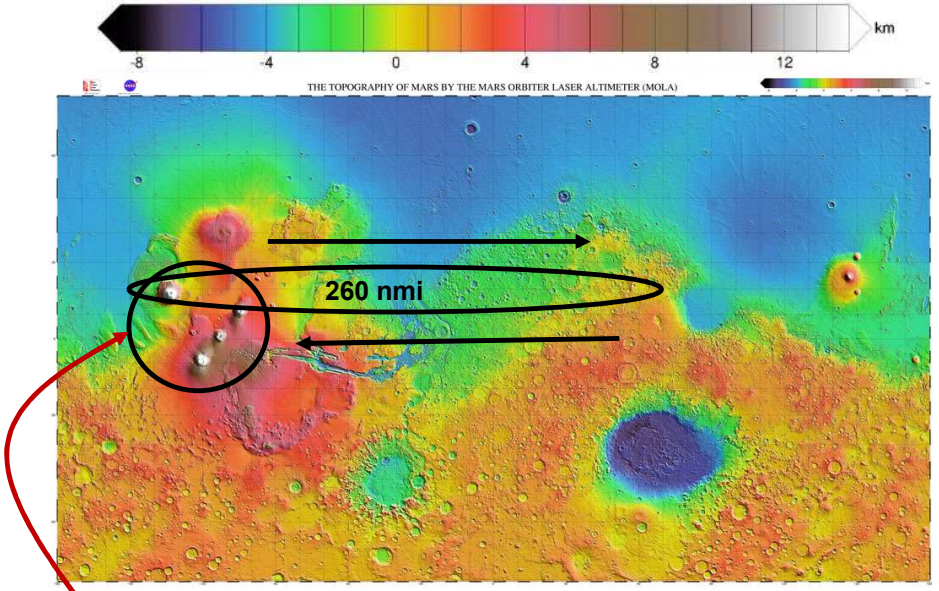


Raymers Manned Mars Airplane

Mission Profile

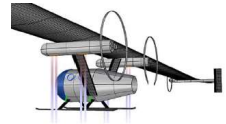
- **For defining the Mission Profile, NASA MOLA 1996 mission has been implemented to the derive the average altitude for Mars.**
- **With the absence of visible water bodies in Mars, sea level cannot be used to determine the flight altitude. Therefore the canyons available can be used as potential Take-off and Landing grounds for high altitude travel**





Potential Take-off and Landing Locations

MOLA (Mars Orbiter Laser Altimeter) to estimate average Mars altitude



Raymers Manned Mars Airplane

Stability and Control Challenges for RMMP aircraft

Disciplinary Challenges

Take -off

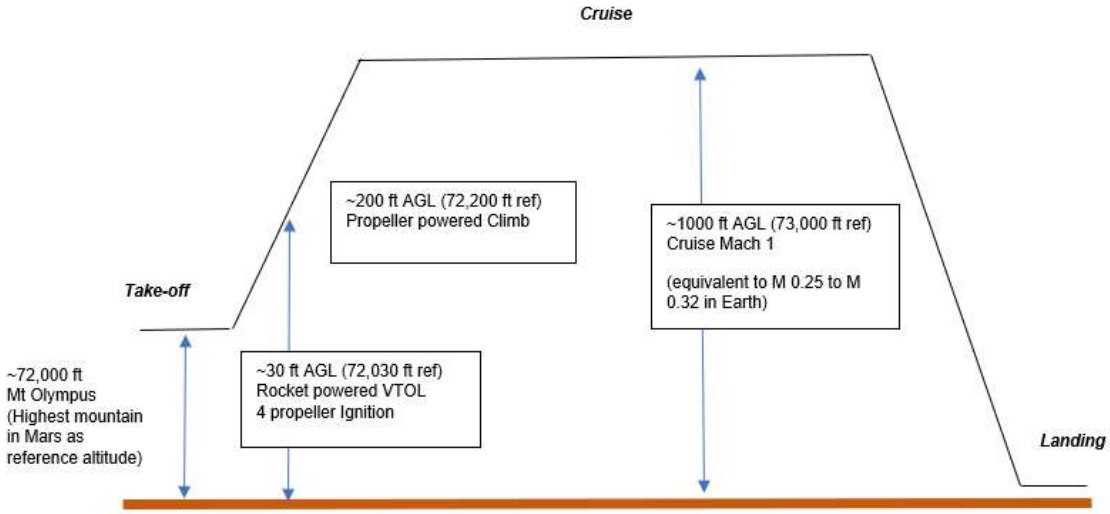
- **Effect of ground effect on longitudinal stability**

Cruise

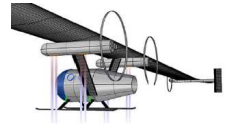
- **Is the aircraft Longitudinally stable?**
  - **a) Do we need additional horizontal Control Surface?**
- **How to determine the Vertical Tail location and its overall effects?**
- **Is the aircraft laterally stable?**
- **Effect of C.G shift on over all vehicle stability?**

Landing

- **Effect of ground effect on longitudinal stability**



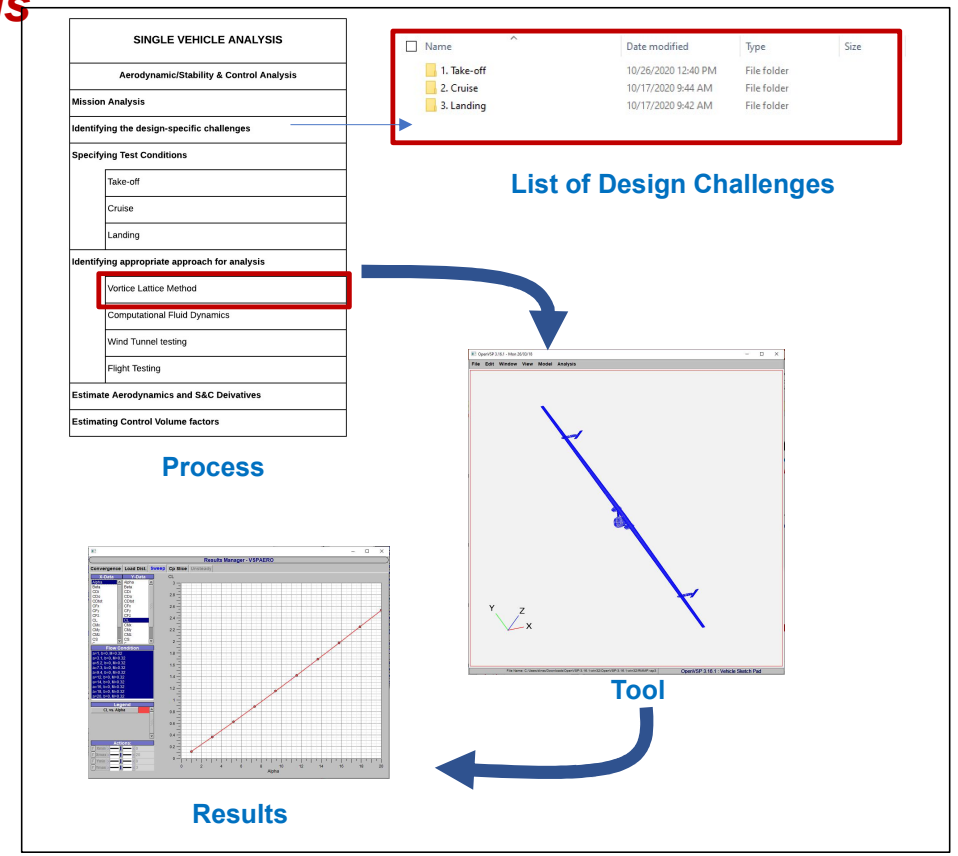
RMMP aircraft prospective S&C requirements



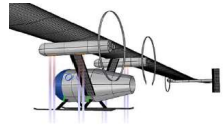
Raymers Manned Mars Plane

Choice of appropriate approach for analysis

- **The crucial step for analyzing the flight qualities of Raymers Manned Mars Plane is to choose an appropriate tool to perform the required analysis.**
- **Considering the nature of the project is a conceptualization of a design, selecting a low-fidelity tool is a best fit for analysis.**
- **Panel Methods like Vortex Lattice Method is suitable for conceptual design and analysis.**
- **OpenVSP software has been implemented for this project to perform the required Stability & Control analysis.**



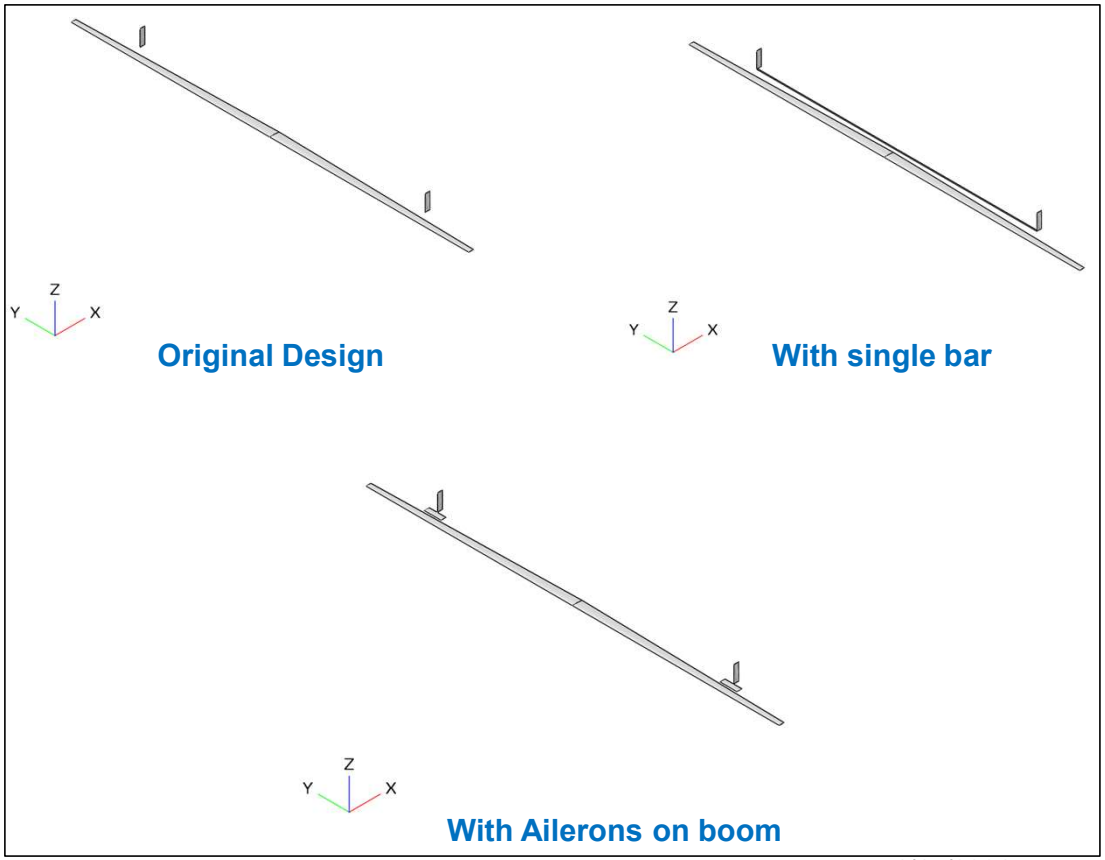
Vortex Lattice Method using OpenVSP method

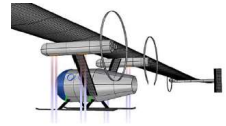


Longitudinal Stability

Is the aircraft Longitudinally Stable?

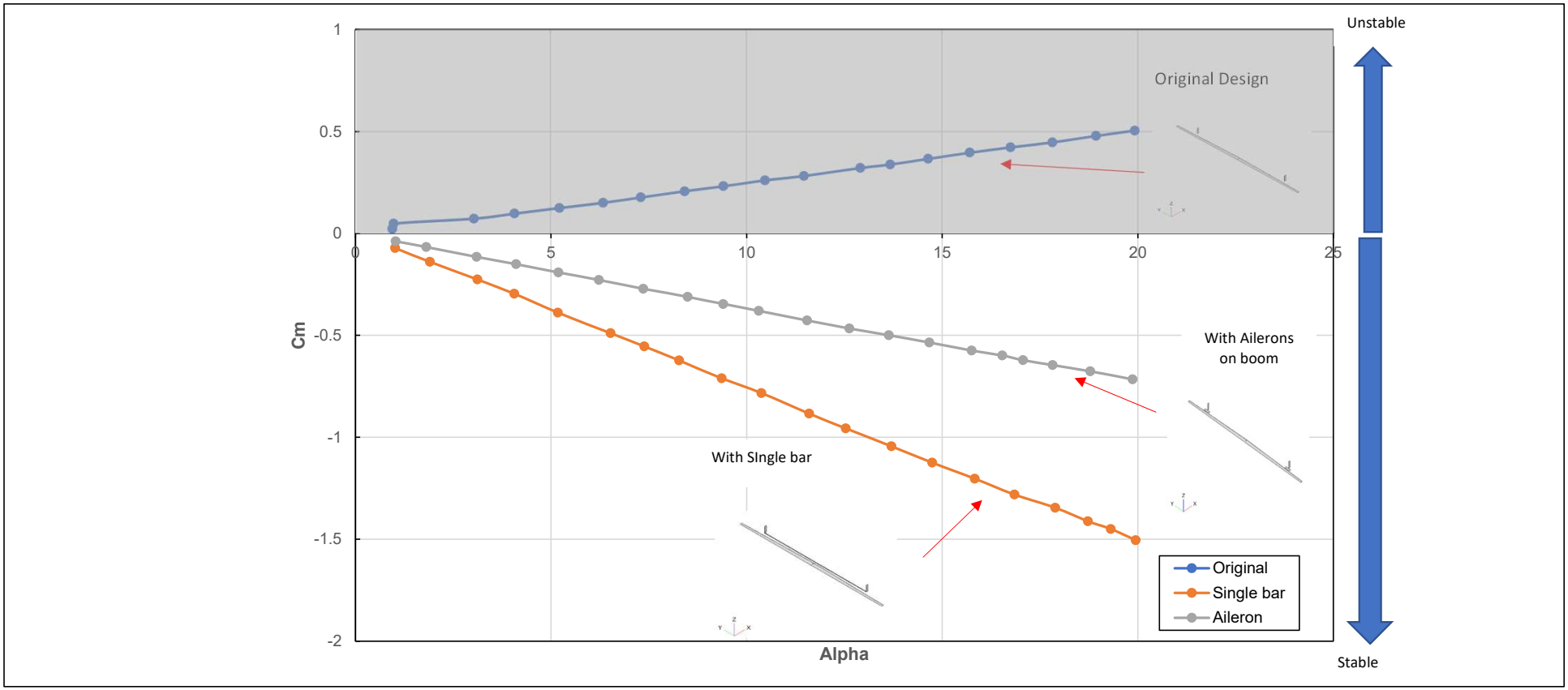
- The longitudinal stability of a high aspect ratio wing aircraft is crucial
- The design is analyzed in the cruise Mach 0.7 on Mars (i.e., Mach No ~ 0.23 on Earth)
- Three different configurations (Original Design, With single bar & With Ailerons on boom) have been analyzed to gauge the original design's capability.
- Adding of additional control surface to existing design can improve the longitudinal stability of the aircraft

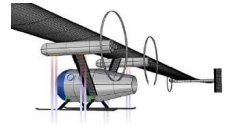




Longitudinal Stability

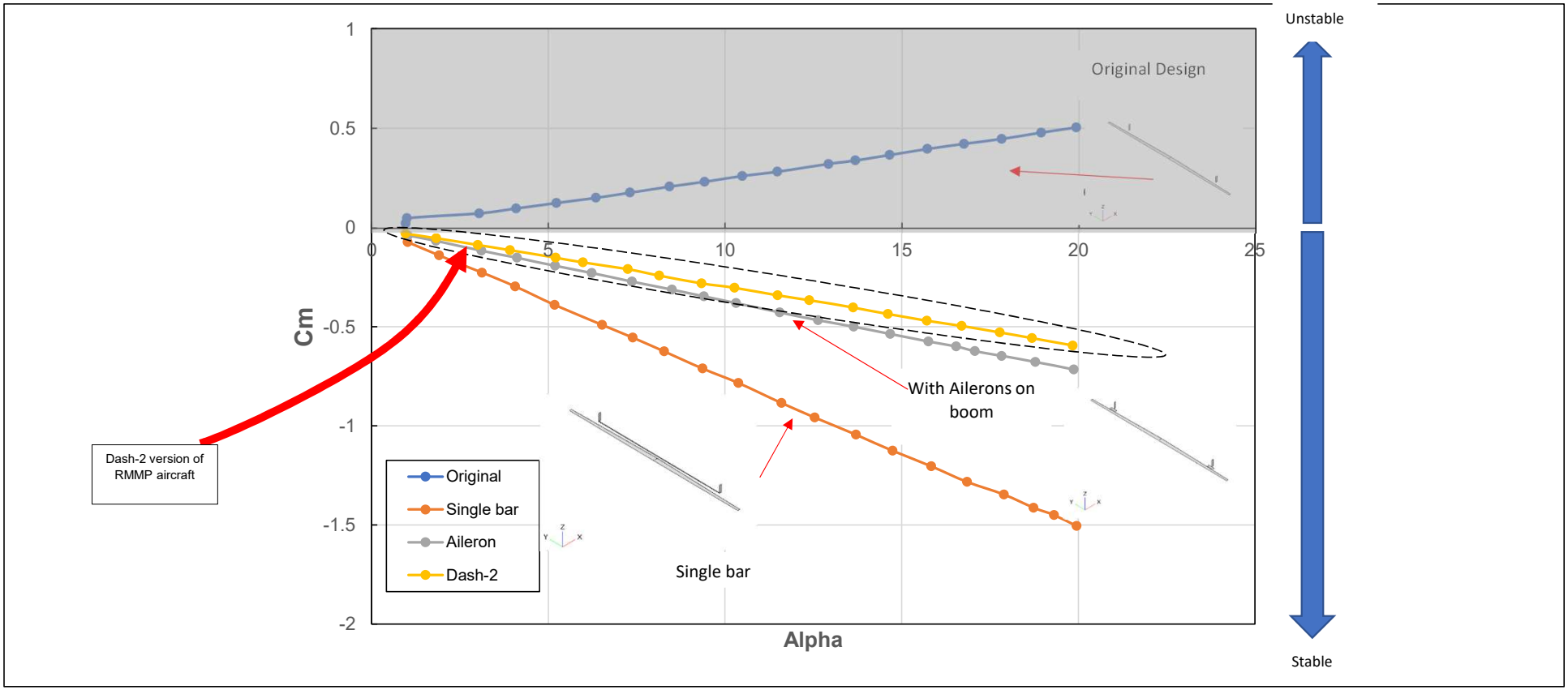
Cm vs alpha

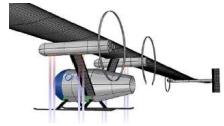




Longitudinal Stability

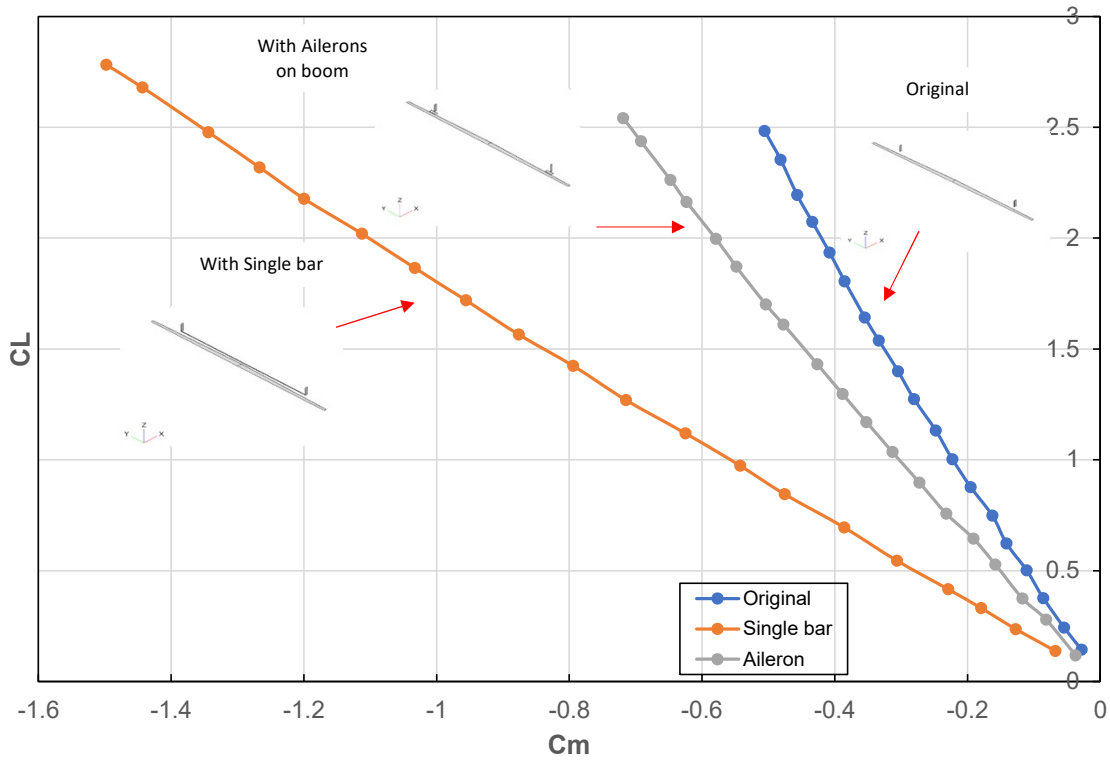
Cm vs alpha (With Dash 2 Version)

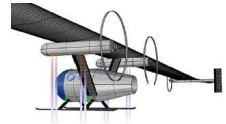




Longitudinal Stability

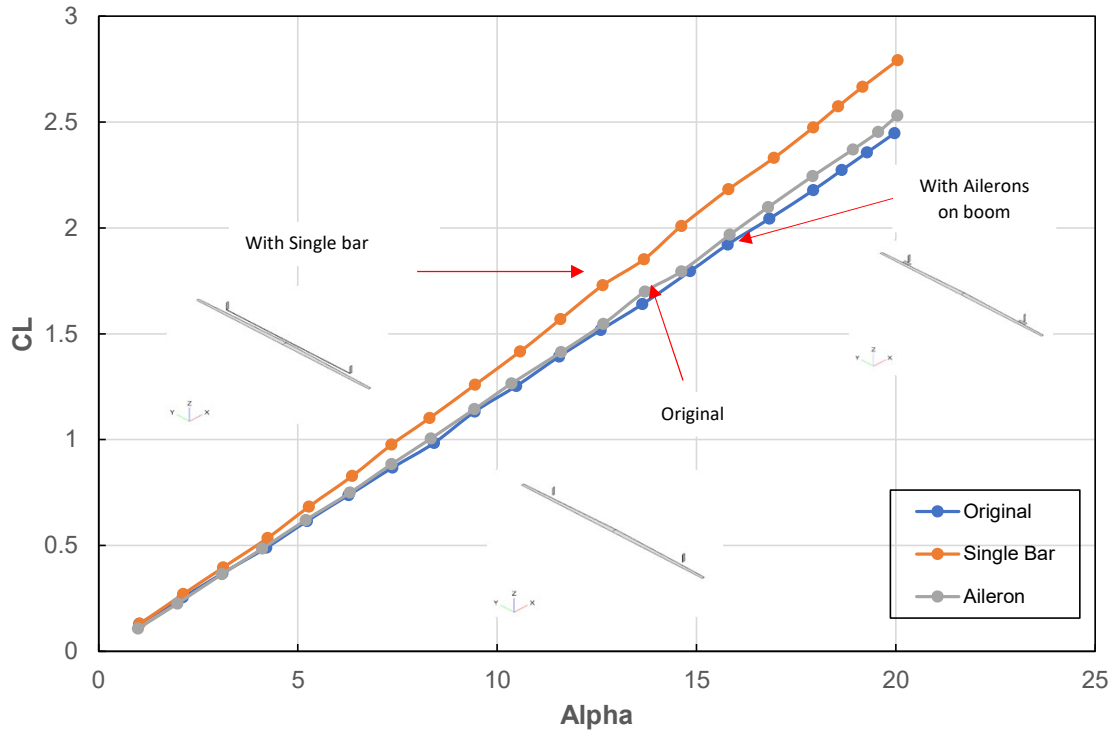
CL vs Cm

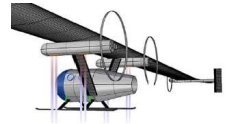




Longitudinal Stability

CL vs Alpha

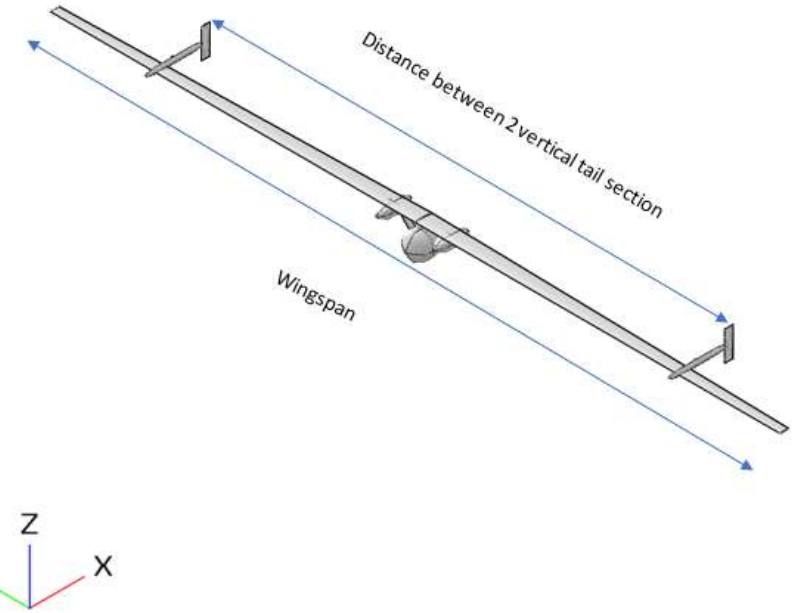




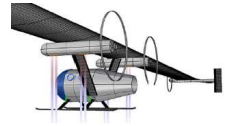
Directional Stability

Effect of Vertical Tail Location on Stability

- **A need for a vertical tail location factor has been visualized to map the effect of different tail location on the aircraft's yawing moment.**
- **The factor gauges the effect of vertical tail location with respect to the wingspan.**
- **Until 50 % Vertical Tail Location factor, the aircraft directionally neutral and becomes more stable at 70% Vertical Tail Location factor especially at low angle of attack and as the percentile increases (70% <), the yawing moment becomes neutral again**

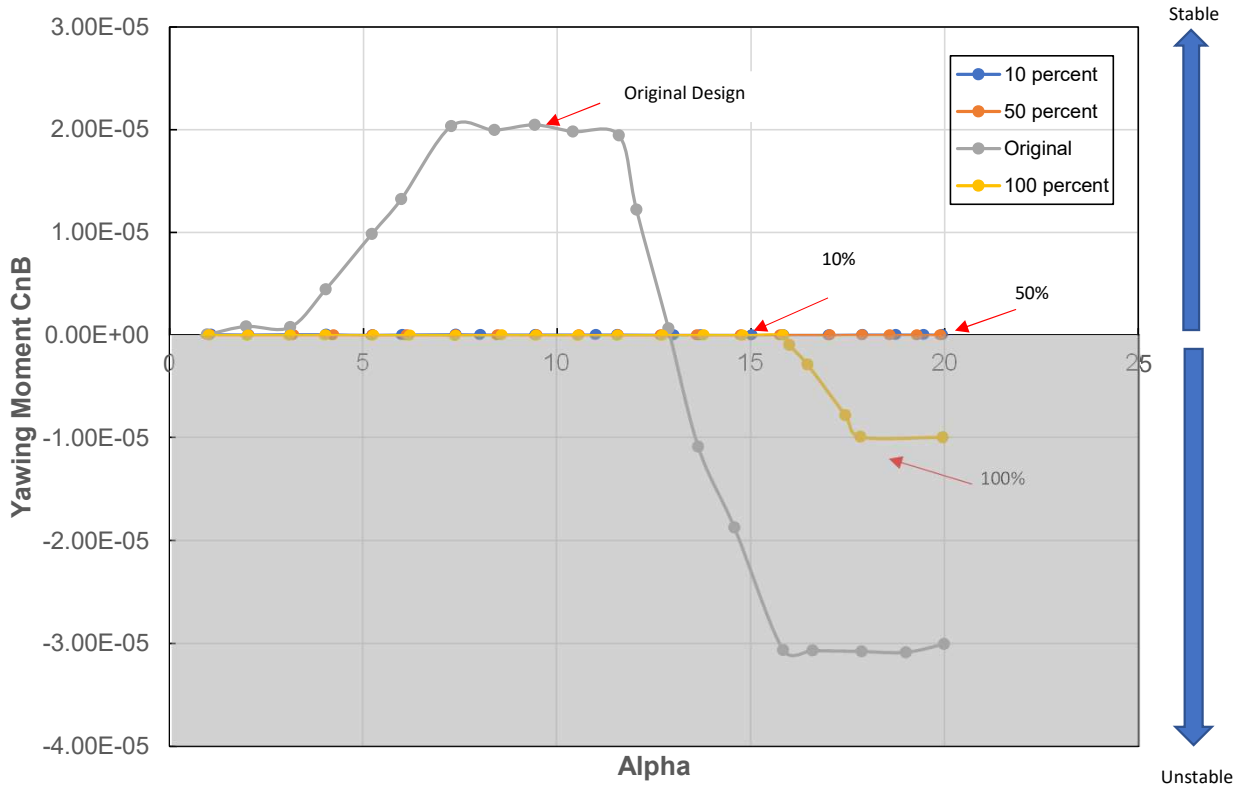


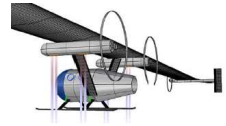
$$\textit{Vertical Tail Location factor} = \frac{Distance\ between\ the\ 2\ tails}{Total\ Wing\ span}\ \%$$



Directional Stability

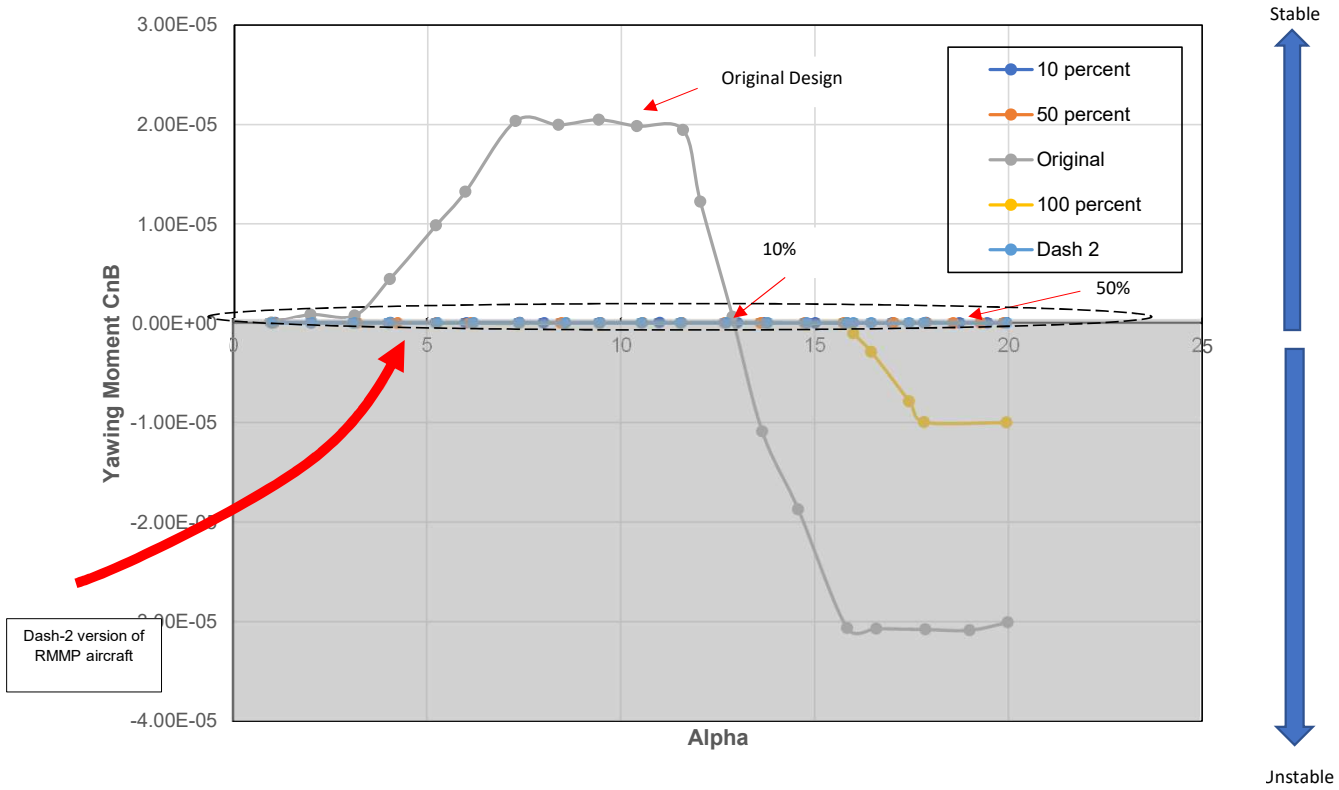
CnB vs Alpha

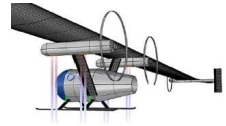




Directional Stability

CnB vs Alpha

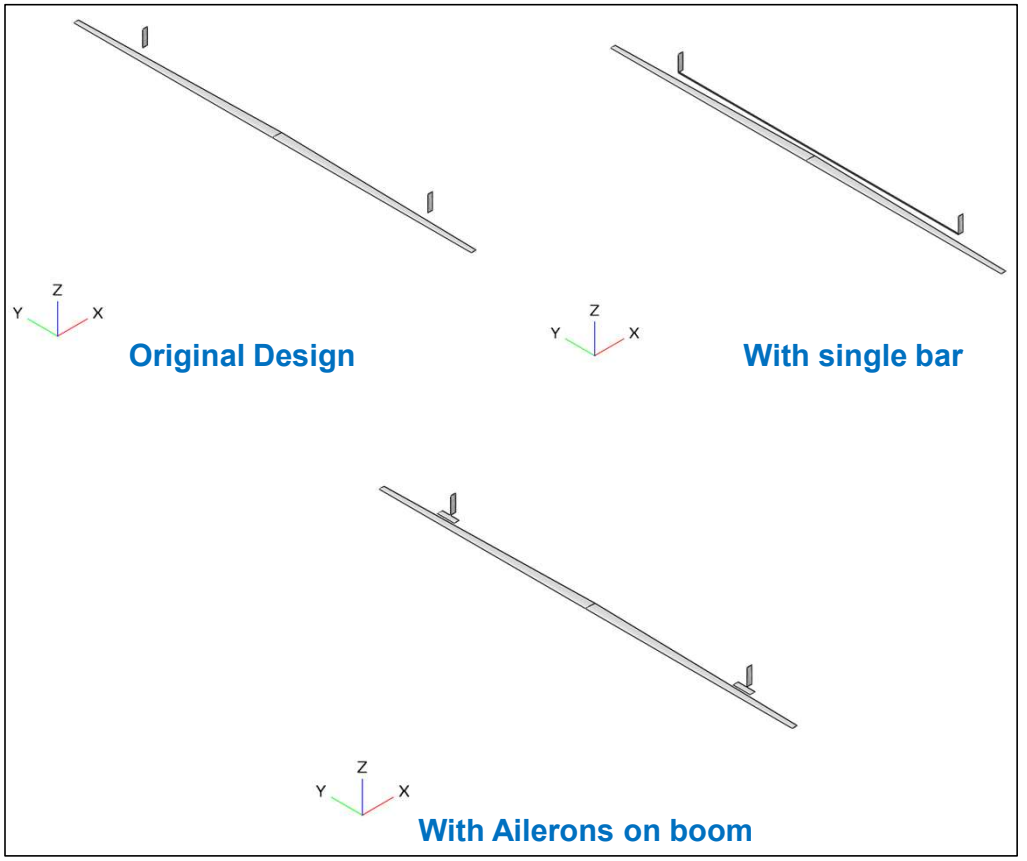


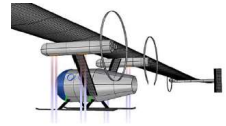


Lateral Stability

Is the aircraft Laterally Stable?

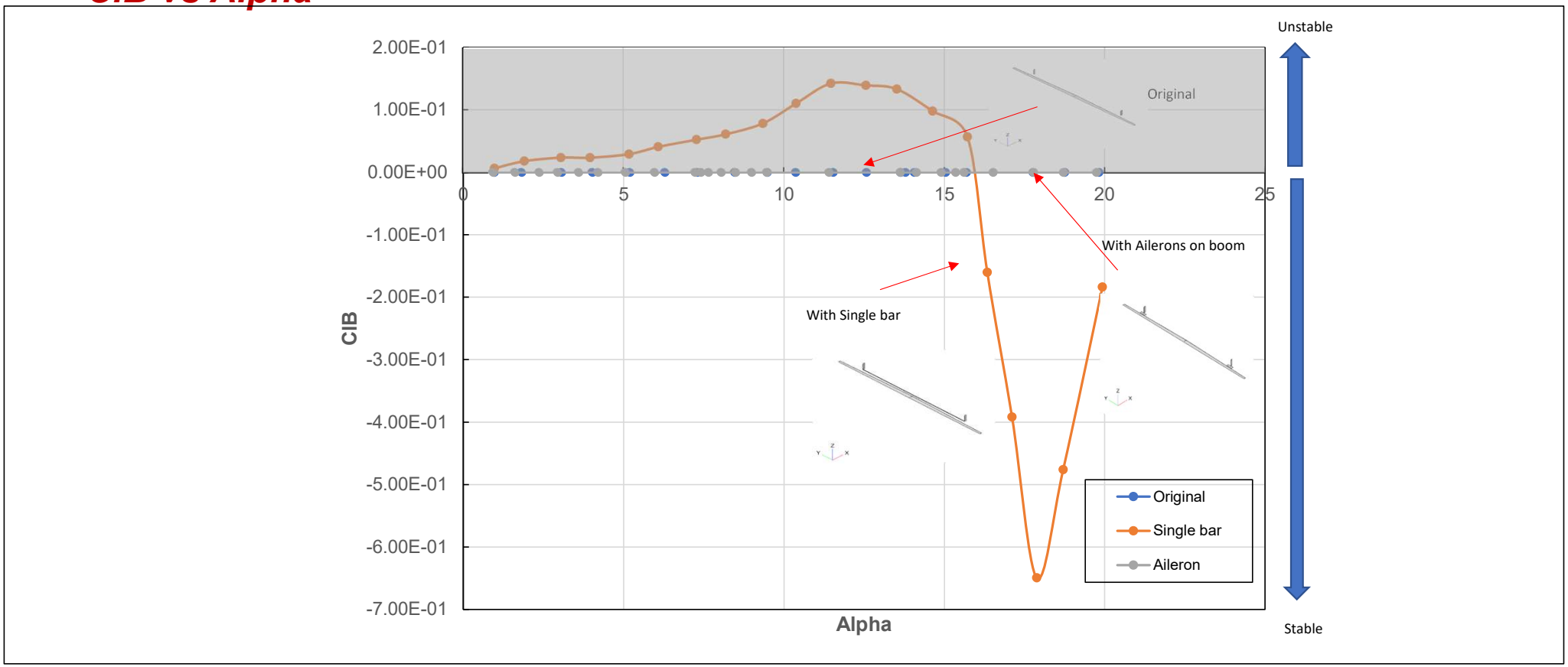
- The Lateral stability of the Raymers Manned Mars Plane is analyzed.
- Like longitudinal stability analysis 3 different configurations have been analyzed to gauge the original design's capability.
- Original design is unstable at high angles of attack.
- Adding a single bar configuration can have stable at higher angles of attack but is unstable at lower angle of attack.
- Thus having Ailerons on boom is an appropriate choice for stable lateral stability at any range of angles of attack

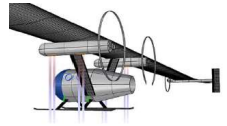




Lateral Stability

ClB vs Alpha

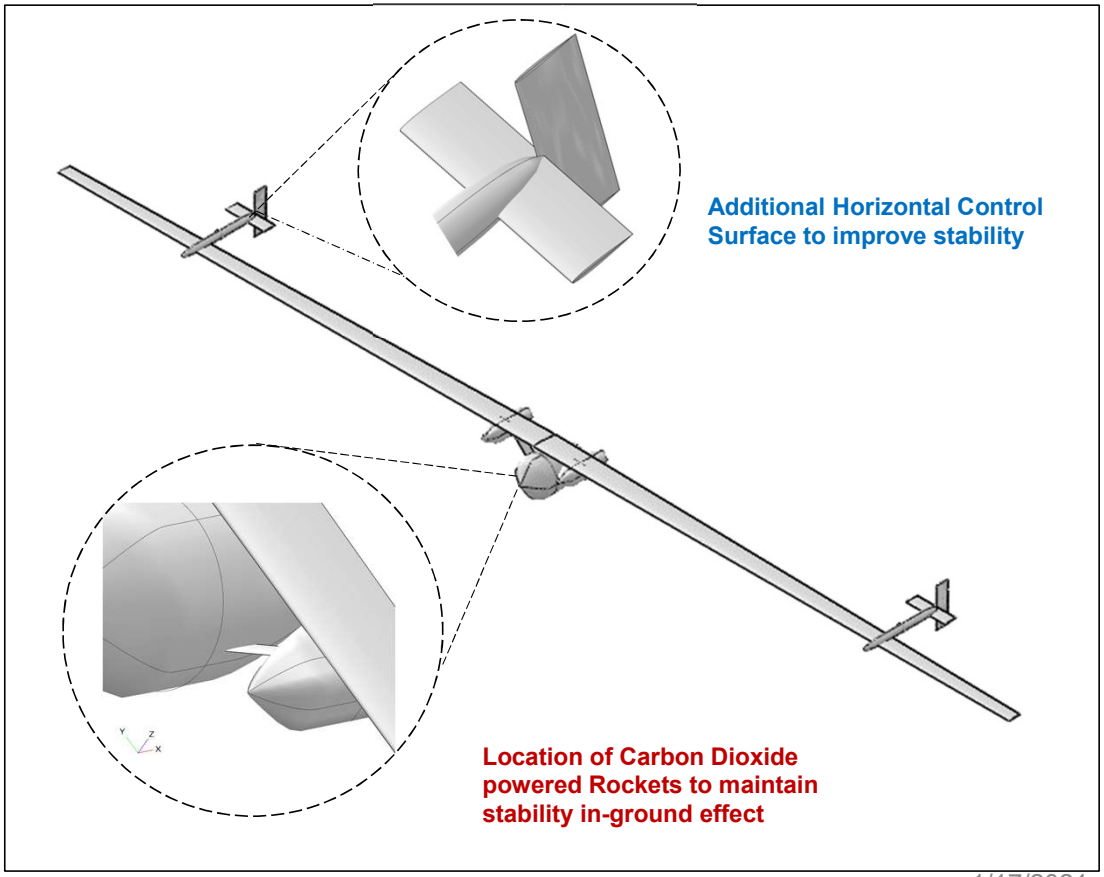


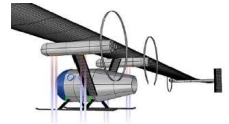


Raymers Manned Mars Plane

Final Product Description

- The suggested modifications after the Stability & Control analysis has been implemented to the design.
- The need for an additional horizontal control surface has been envisioned for the RMMP design to improve the Longitudinal and Lateral stability characteristics of the aircraft.
- For a large wingspan aircraft like RMMP aircraft, the location of twin boom across the span is crucial for lateral stability.

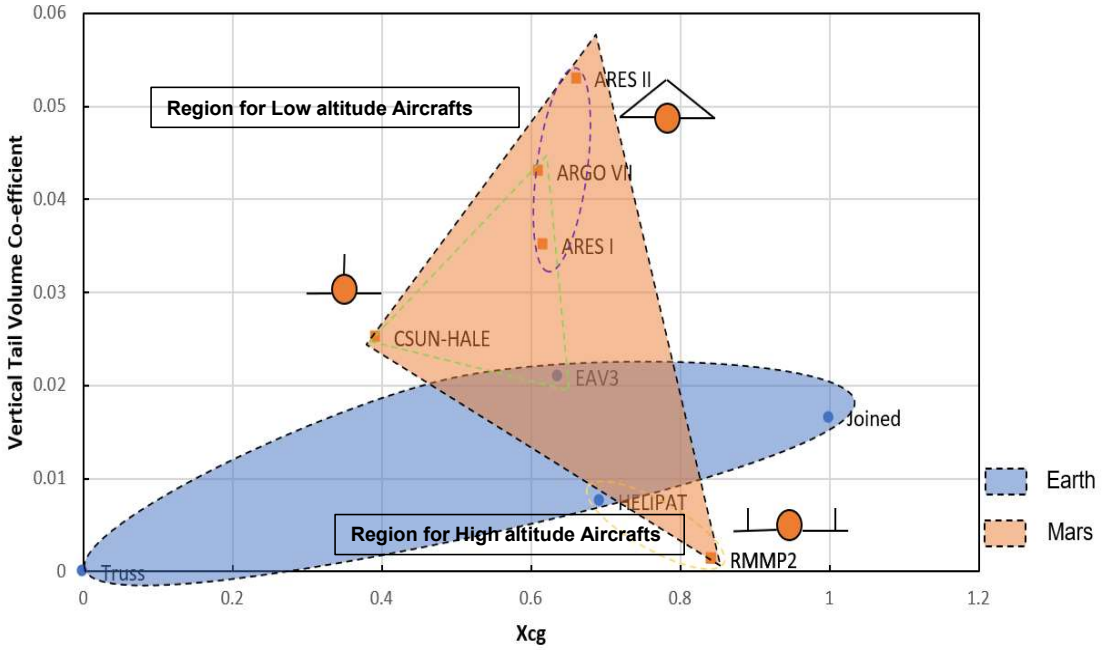




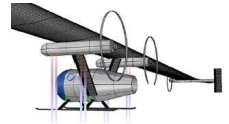
Control Volume

Vertical Tail Volume

- The vertical tail volume co-efficient is crucial to size the aircraft's control surface for directional stability.
- A comparative study has been conducted wherein the control surface volume is compared with both Earth-Bound and Martian applications.
- Since RMMP is a high-altitude aircraft, the vertical control volume coefficient is less compared to low-altitude aircra travel.
- Compared to an Earth-Bound Twin boom aircraft like HELIPLAT, RMMP aircraft has low Vertical tail volume.



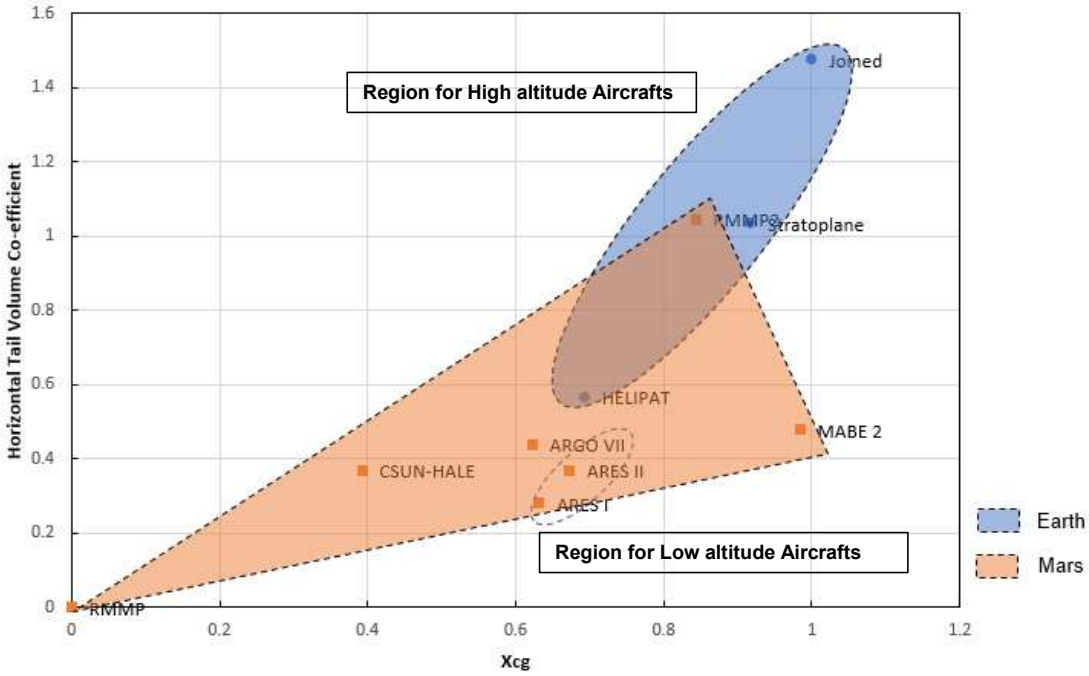
Vertical tail volume co-efficient



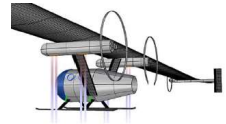
Control Volume

Horizontal Tail Volume

- The Horizontal tail volume co-efficient is crucial to size the aircraft's control surface for longitudinal and lateral stability.
- A comparative study has been conducted wherein the control surface volume is compared with both Earth-Bound and Martian applications.
- Since RMMP is a high-altitude aircraft, the horizontal control volume coefficient is more compared to low-altitude aircraft travel.
- Compared to various Earth-Bound HALE aircrafts and sailplane like HELIPLAT, RMMP aircraft has higher Horizontal tail volume.



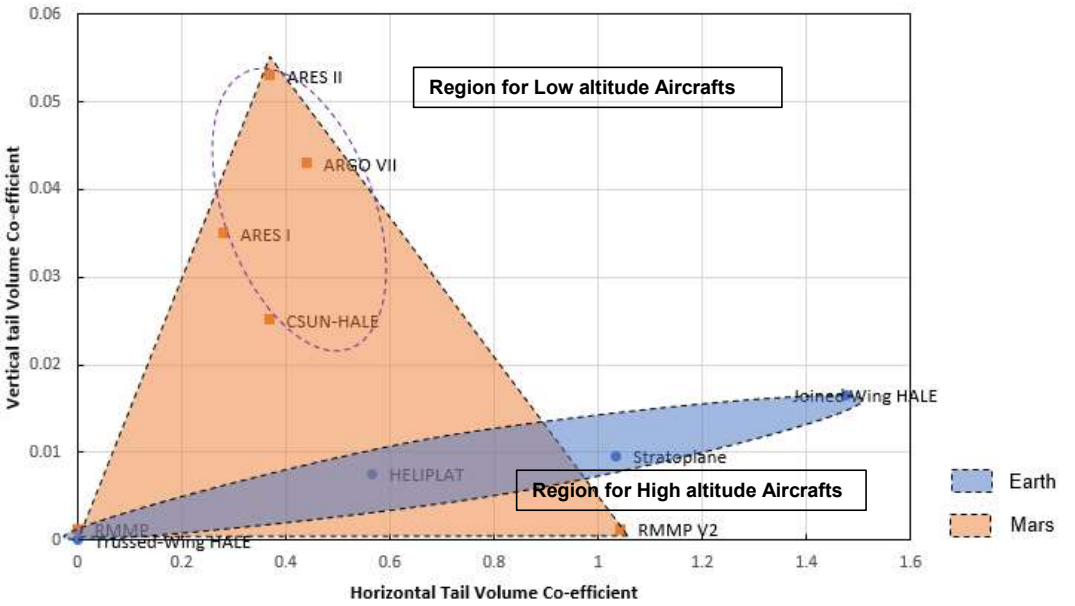
Horizontal tail volume co-efficient



Control Volume

Horizontal tail vs Vertical Tail Volume

- **The horizontal and vertical tail volume co-efficient comparison has been conducted.**
- **In general trend, vertical tail volume co-efficient is inversely proportional to horizontal tail volume co-efficient.**
- **Compared to low- altitude air travel, for high altitude aircraft the vertical tail volume is less for high horizontal tail volume co-efficient.**
- **For Mars and Earth based platforms, the vertical tail volume and horizontal tail volume co-efficient for RMMP is less compared to Earth-bound aircrafts**



Horizontal tail vs Vertical volume co-efficient