Aerial Atmospheric Vehicle for Mars

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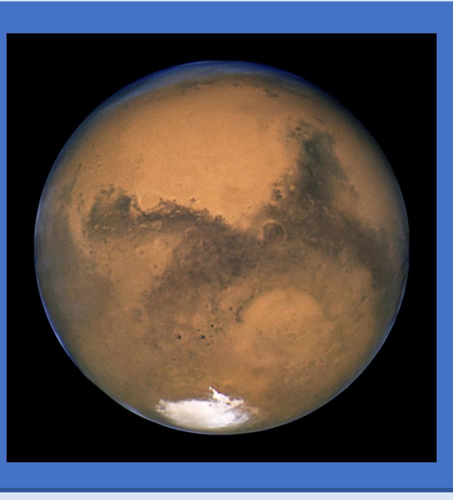


ABSTRACT

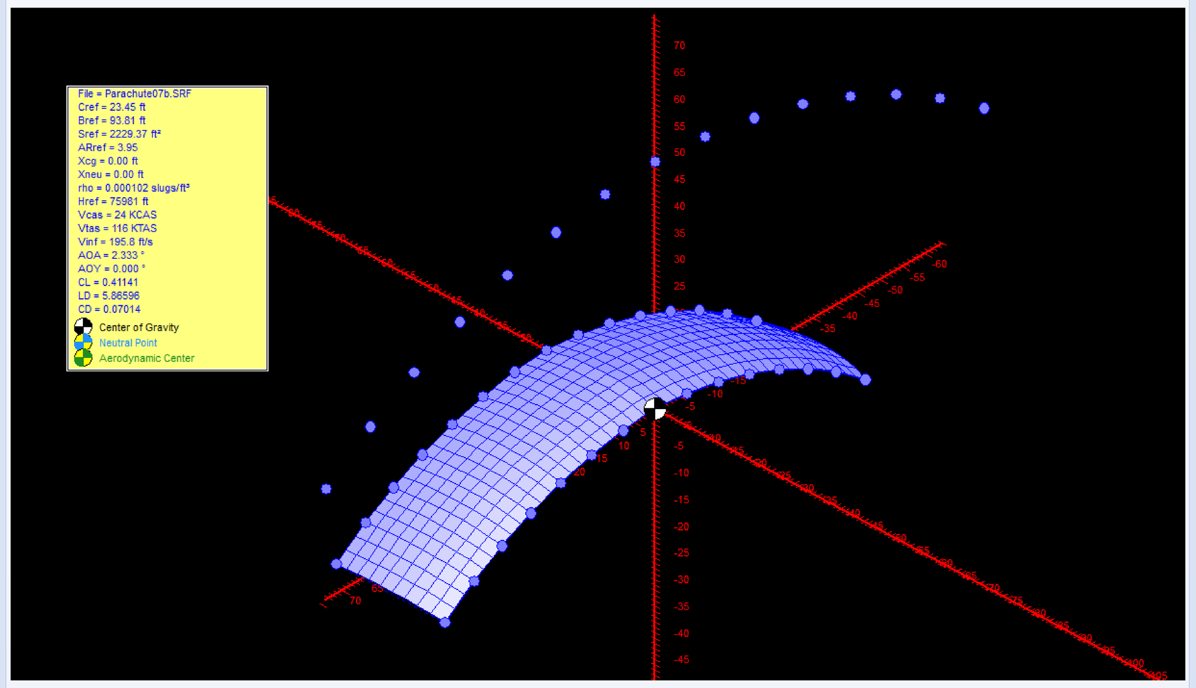
To support possible future human presence on Mars where bases are likely to be spread apart, an aerial vehicle could be used to transport crew and cargo between them. Designing such a vehicle is very challenging because of the low atmospheric density on Mars compared to Earth. A conventional fixed-wing airplane concept intended for Mars was presented by a team of aircraft designers in 2020 and was shown to be feasible. However, that study did not take into consideration how to transport a large airplane to Mars. This study evaluated an alternative concept involving a powered parachute vehicle weighing less than a third of the fixed-wing airplane and being easier to transport to Mars by spacecraft. Aerodynamic and performance analysis was done by hand calculations and a Computational Fluid Dynamics (CFD) based aircraft design software to achieve a conceptual design for a powered parachute vehicle that could operate on Mars. This study revealed that such a concept is possible, but a future study might determine a better configuration than the one presented here.

INTRODUCTION

- Operating an aircraft on Mars is very challenging due to the low atmospheric density.
- Average atmospheric density on Mars is about 1/60 of that on Earth.
- However, acceleration due to gravity at the surface of Mars is only 37.9% of that on Earth.
- This means an aircraft wing for use on Mars needs to have 23.13 times the surface area of one for use on Earth to sustain flight at a certain airspeed.
- Therefore, a very large wing is necessary.
- Large wings add a lot of weight to a vehicle.
- Using a parachute wing instead of a fixed-wing configuration could drastically reduce weight.
- However, parachute wings generate more drag than airplane wings.
- Wing area can be significantly reduced by increasing operating speed.
- However, higher operating speeds complicate the takeoff and landing process, introducing the need for a ground launch and capture system.
- Because piston and turbine engines will not work on Mars and rockets not being very efficient, electric propulsion was chosen for this concept.

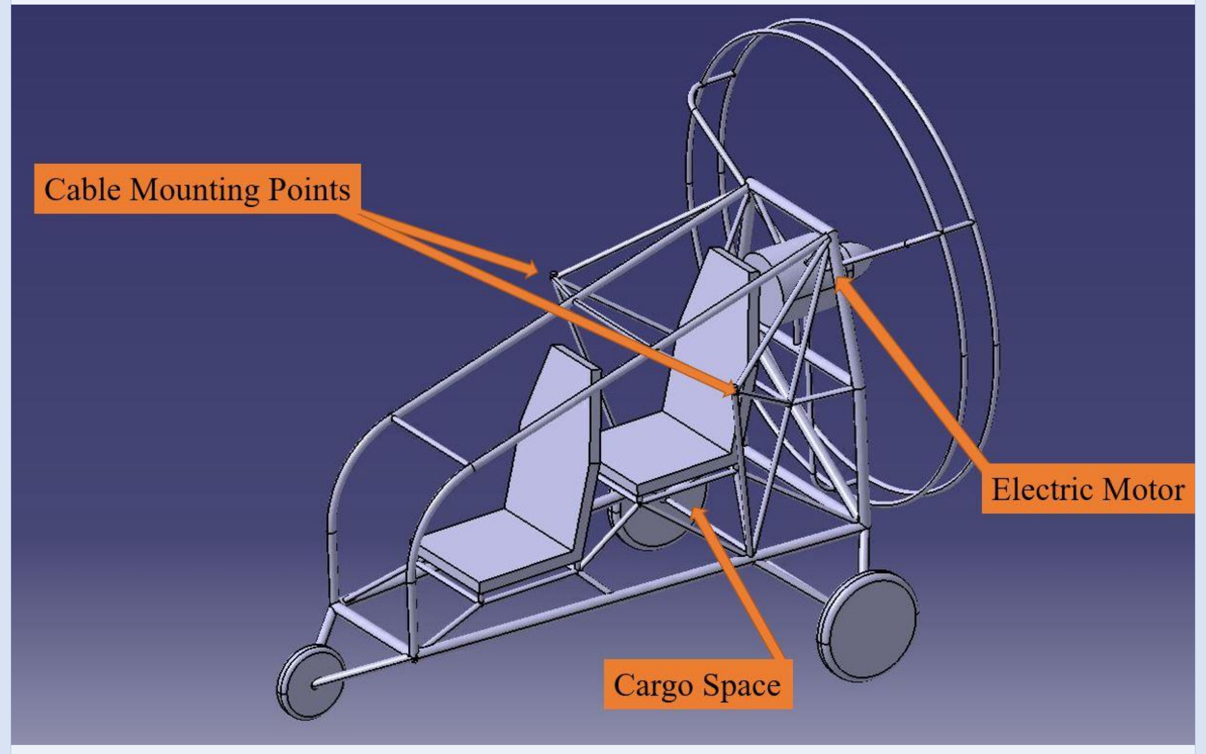
METHODS

- This study built on a previous study led by Dr. Daniel P. Raymer on a fixed-wing airplane concept weighing 6000 lb_f and having a large wing [1].
- That study showed that such a concept is possible but did not consider how to transport such a vehicle to Mars.
- Our study initially tried to improve upon the fixed-wing concept but switched to investigating a powered parachute type vehicle.
- Using simple hand calculations, data from research papers on parachute aerodynamics, and a CFD program called Surfaces, a wing planform together with its aerodynamic characteristics was obtained.



Surfaces CFD model used to compute lift and drag.

- Using CATIA V5, a model of a crew compartment capable of seating two people and carrying cargo under the passenger seat was created.
- The passenger seat together with the cargo space and the cable mounting points are positioned as close to the center of gravity as possible.
- This allows for the vehicle to fly with or without passengers and cargo without having to shift weight.



3D model of crew compartment in CATIA V5.

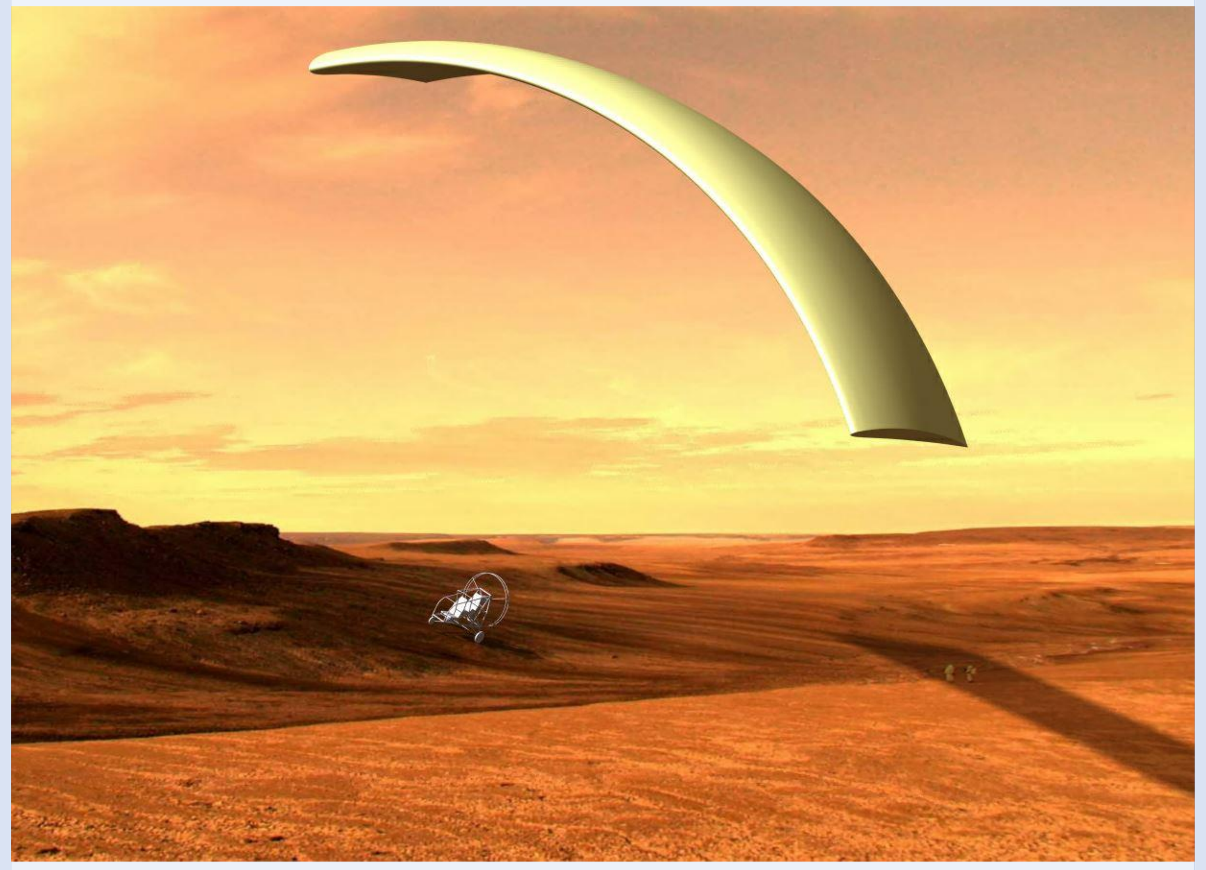
RESULTS

- A vehicle concept weighing around 1800 lb_f on Earth (682.2 lb_f on Mars) was obtained through hand calculations and CFD analysis.

Parameter	Value
Mean aerodynamic chord, C_{ref}	23.45 ft
Wingspan, B_{ref}	93.81 ft
Wing reference area, S_{ref}	2229 ft^2
Vehicle weight	1800 lb_E (682.2 lb_M)
Aspect ratio	3.95
Cruise speed, V_{TAS}	116 KTAS
Cruise angle of attack	2.33°
Cruise lift coefficient, C_L	0.41141
Cruise drag coefficient, C_D	0.07014
Cruise lift to drag ratio, L/D	5.86596
Airfoil	NACA 6412
Power Required (climb)	127 BHP
Power Required (cruise)	69.5 BHP
Range	340 km (211 miles)

Vehicle specifications list

- This vehicle would cruise at an airspeed of 116 knots (133 mph) near the surface of Mars.
- Its wing area would be comparable to that of Raymer's concept and the Boeing 757 jetliner.
- Because parachute wings are made of fabric, they can easily be packed and, together with the crew compartment, brought to Mars on a single rocket like the SpaceX Starship.



Artist's impression of vehicle flying on Mars [2].

CONCLUSIONS

This study showed that a well-designed vehicle of this type could potentially operate on Mars. The main advantages of a powered parachute vehicle over a fixed wing aircraft are simplicity, low weight, and ability to bring to Mars on a single spacecraft. The main disadvantage is that parachute wings generate up to 3x as much drag compared to conventional airplane wings. This results in less range, but 340 km is likely to be more than enough for early settlers on Mars. Powered parachute vehicles are easier to launch and recover over short distances because they don't have fragile wings that can break off during high accelerations. This study only evaluated some of the issues involved with flying such a vehicle on Mars and there are many more that need to be solved before this concept can become reality.

FUTURE AREAS OF RESEARCH

- Low Reynolds number environment on Mars adversely affects performance by causing wings to stall early and increasing pressure drag. This might require a different airfoil.
- Methods for keeping the parachute inflated during flight would need to be evaluated.
- An elliptical wing could further reduce drag but might adversely affect other flight characteristics.
- Smaller versions could be sent to Mars on future spacecraft to verify this concept.

REFERENCES

[1] Raymer, D., French, J., Finger, F., Gómez, A., Singh, J., Pillai, R. G., Monjon, M., de Souza, J. M., and Levy, A., *The Raymer Manned Mars Airplane: A Conceptual Design and Feasibility Study*, American Institute of Aeronautics and Astronautics, 2021

[2] Mars wallpaper: http://hdinwalpapers.blogspot.com/2013/11/mars-wallpapers.html

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