CONCEPTUAL DESIGN OF AN UNMANNED AERIAL VEHICLE FOR MARS EXPLORATION (M.I.S.C.A.V.).

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Introduction: The advent of the refocusing of the scientific lens on the exploration of Mars has necessitated divergence from the explorative methods used in past missions. From various literature on long term Mars exploration, in particular the Mars Direct Proposal [**1**], the location of subsurface mineral and water deposits is of primary importance to manned missions to Mars. With the rise in understanding of the Martian atmosphere and weather patterns, the feasibility of aerial missions has increased to a level where certain missions are more practical with aerial explorers. This report focused on the design of the Mars Inflatable-wing Solar Continuous Aerial Vehicle (MISCAV)

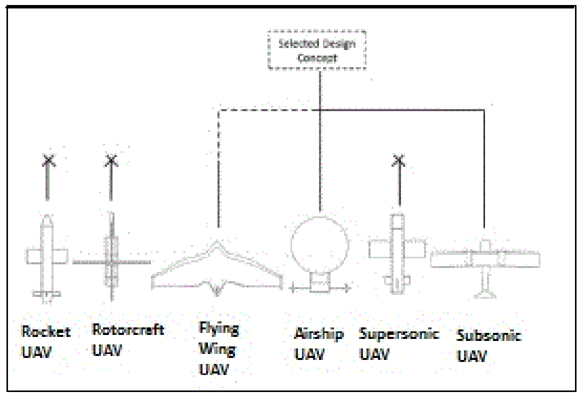
Aerial Explorers: Given the rough terrain of the Martian landscape, unmanned aerial vehicles offer greater mission range than ground based vehicles, while not being limited by the decreased resolution of satellite mounted sensors due to the Martian mesosphere. While the low pressure and density of the atmosphere can be detrimental to the efficiency of aerial vehicles, this is outweighed by the flexibility of the vehicle. As ground exploration rovers have had some success in the past decade, the concept of aerial exploration techniques has not been fully developed to date.

Mission Design: From an analysis of the purpose of the location and mapping of subsurface mineral and water deposits, the UAV was determined to require the following mission features to complete the mission: extreme range, low maneuverability, high cruise altitude range, ability to operate in low Reynold's Number régimes, consume minimal power, be powered by non-oxygen combustion powerplants and have a low packed size for Earth to Mars transit.

The UAV must also carry a mission specific payload, including: a Ground Penetrating Radar, for detection of hydrogenated clays [**2**], subsurface ice or subsurface liquid water deposits, a magnetometer series for location of the primary mineral targets[**1**] and

Concept Creation: From an analysis of previous Mars mission vehicles and proposed Mars aerial vehicles, a set of design trends were used in the conceptual design of the MISCAV including: cruise velocity of approximately M 0.5, prevalence to blended wing body designs, limiting propulsion systems to electric or closed hydrazine powerplants and an aspect ratio of approximately 14.

Conceptual Layout. From this, a selection of aerial vehicle types were analyzed with respect to the mission, including; Rocket, Rotorcraft, Flying Wing, Airship, Supersonic and Subsonic UAV's were compared with respect to their suitability for the operating environment and mission. The various concepts were rated against: mass, endurance, range, powerplant availability and hostile weather capabilities; from the conceptual analysis, the Airship, Subsonic and to a lesser extent, the Flying Wing layout were found to be most suitable, and the final concept was determined to be a subsonic UAV, with wings filled with a lighter-than-atmosphere gas that are blended with the fuselage.



Final Concept. The finally vehicle was designed to have 70% of the neutral buoyancy at cruise altitude from the helium lifting gas, and the remaining lift force from the flow over the airfoil section. In keeping with the endurance, power and cruise velocity requirements, the powerplant was designed as a solar powered electric propeller, and was designed to operate continuously at a low velocity.

Design Process: The approach employed for the conceptual design of the MISCAV is complicated by two main factors: the employment of an inflatable wing structure and the mission profile of continuous flight. Therefore the design process was based on energy balances during steady level flight, where the weight force is balanced with the dynamic lift and static lift forces, and the total solar energy collected during daylight hours is balanced with the net energy used by the powerplant and payload. The various sizing and design parameters were determined as relationships rather than empirical values, and the design process was created as an iterative, rather than a static process [3].

Sizing Designs: Rather than design to a specific cruise altitude elevation, the MISCAV was designed to a specific cruise atmospheric density, owing to the vast differences between the day and night cycles and the pressure of the lifting gas within the wings.

Lifting Gas Volume. Due to the correlation between the volume required for the MISCAV and the dimensions of the wings, the volume corresponds to a finite set of wing thickness, span and area relationships.

Solar Energy Balance. By analyzing the efficiencies of electrical componentry, the total function of power consumed was determined, as a function of the model established to approximate the model created to approximate the amount of solar energy available on the Martian surface, to include for day night divides, atmospheric inefficiencies and battery charge and discharging efficiencies.

Fixed Masses. Due to the outline of the mission, there are a number of fixed masses that are attributed to the mission dynamic, including the payload and avionics masses. As the MISCAV has no comparable aircraft, mass estimation methods used for ultralight solar aircraft were used to determine the structural mass of the vehicle. By using industry standard estimation methods [Ref] the fixed masses for the mission were determined.

Solar Cell Sizing. As solar cells provide all the energy for thrust and thus part of the lift, the cell sizing is directly related to the T/W ratio of the MISCAV. As the solar cell sizing directly links to the power consumption of the system and the wing dimensions, the surface density and cell encapsulation can be used in the MISCAV iterative design process.

Propulsion System. By determining that the torque of the electric motor can be defined as a function of the mass to power ratio. By comparing the factors to the necessitations required for level flight, the propulsion system can be related to the sizing estimation of the MISCAV unit.

Energy Balances: The previously mentioned energy balances were used to determine the sizing of the MISCAV, by modeling the features as a function of thrust and cruise velocity. By predetermining and assuming a set of parameters, various sets of aspect ratios, mass' and wingspans were identified. To estimate the mass, various parameters were compared to iterations of the MISCAV's possible aspect ratio amounts. Each aspect ratio analyzed was compared to a range of possible half-wingspan values (the length of one wing section) rather than the wingspan, to better allow for the computation of the volume of gas available to lift the wing (as the inflatable section of the wing is not measured as the wingtip to wingtip length).

As a comparative baseline, the single wing span was used as the comparable factor and was compared to the: wing volume, total mass, wing area, cruise velocity, propeller power and percentage of area covered by solar cells were equated for specific aspect ratios. From the results of the reiterative cruise energy balance an aspect ratio of 16 was found to have the greatest trade-off between wing span and wing volume. Using the iterative method, and selecting an airfoil with greatest area and low Reynold's Number performance, the following sizing parameters were created for the MISCAV.

Wing Span	20 m
Aspect Ratio	16
Mass	51.3 kg
Wing Surface Area	10.2 m^2
Propeller Power	121.2 W
Solar Cell Area	7.752 m^2
Wing Chord	1.25 m
Cruise Velocity	54.2 $m.s^{-1}$

Part Sizing: From the above conceptual sizing, the individual parts were able to be sized. The NACA 4318 airfoil [4] was selected for the inflatable wing, with spars inflated to a pressure of 200 kPa. The empennage sizing was sized to standard aerospace techniques, in an H-tail configuration. The deflated wings were determined to be able to be packed into a rolled volume of 0.1786m^3 per wing. In order to keep the propeller tip speed below the local speed of sound, it was sized for a shaft velocity of 600 RPM with a radius of 1.74m.

Vertical Stabilizer Area	2 x 0.533 m^2
Horizontal Stabilizer Area	2.0 m^2
Distance from COG	7.5 *m*
Propeller Power	121.2 *W*
Number of Blades	3
Blade Radius	1.74 m

Conclusion: While operations on Mars offer both design and mission complications, the MISCAV can be conceptually designed to complete the mission of subsurface mineral and water detection. Further research must be conducted to assess the viability of using inflatable structures in the Martian atmosphere, while additional work must go into the design of the specifics of the MISCAV unit.

References: [1] Zubrin, R. (1996). *The Case for Mars: The Plan to Settle the Red Planet and Why We Must.* New York: Free Press Inc. [2] Rajendran, S., et.al. (2007). Mineral Exploration: Recent Strategies. New Delhi: New India Publishing Agency. [3].Noth, A. (2008). Design of Solar Powered Airplanes for Continuous Flight, Master's Thesis. ETH Zurich, Switzerland. [4].Oyama, A, Fujii, K. (2004). Airfoil Design Optimization for Airplane for Mars Exploration. Tokyo: JAXA Publishing.