Robotic Rigid Vacuum Airship for Exploration of Mars

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THE NEED TO BE AIRBORNE ON MARS

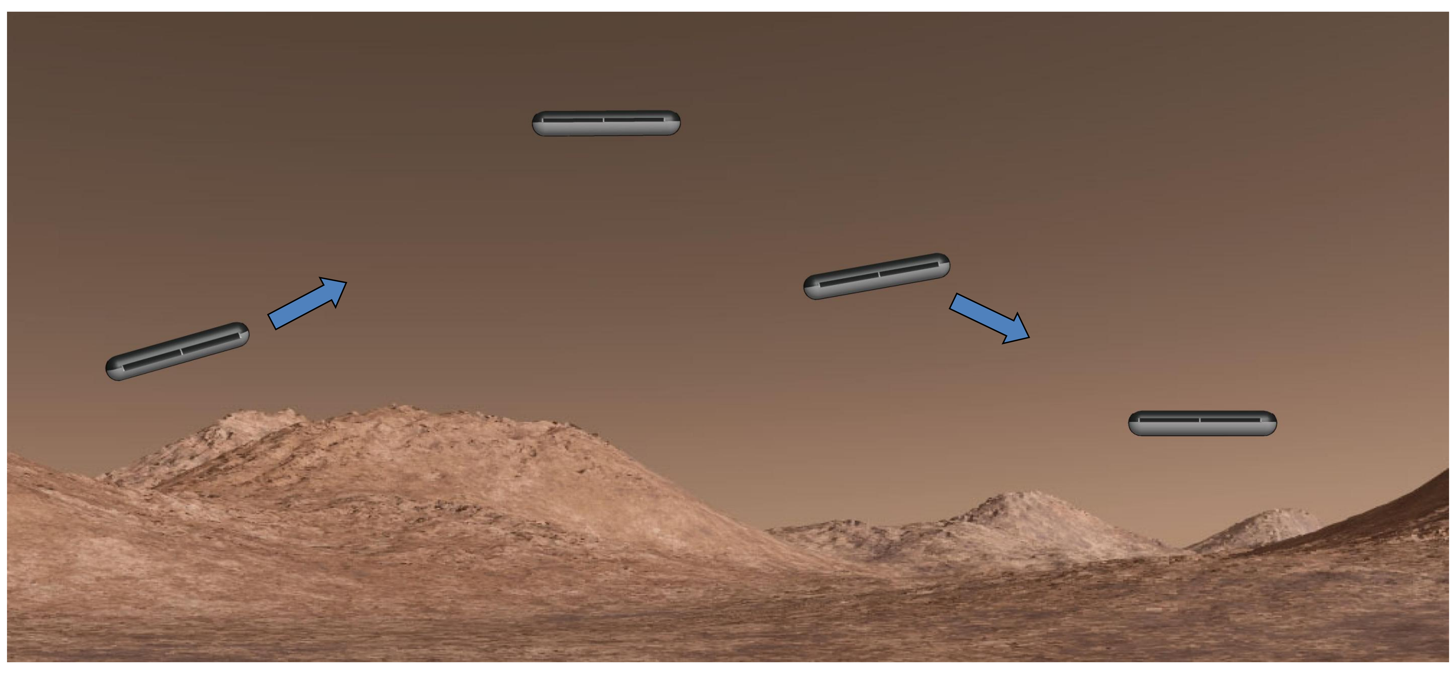
Land-based exploratory vehicles like the Mars Exploration Rovers have typical navigation range of less than a hundred meters a day and so have to be deployed close to the targets of interest. The Mars Express and the Mars Science Laboratory are being designed to further extend the range but they too will have severe restrictions over the area and terrain they can explore. Unmanned Aerial Vehicles on the other hand is ideal for exploration of vast swathes of the atmosphere of Mars especially while studying the occurrence of Methane. Airplanes and rotorcrafts have a relatively far lower operational life and being fast moving will pose restrictions to study in addition to requiring a solar-collector area of 7.5 times greater than it would be required on Earth to fly the same payload.

WHY VACUUM AIRSHIPS ?

The Lighter Than Air (LTA) systems being very energy efficient are best suited for aerial tasks. They are slow-moving, have a very large surface area for photovoltaic cells, can allow long-range as well as close-up observations, they can carry their payload of instruments and equipments and deploy them over vast distances. They are capable of directly sampling of the atmosphere at various altitudes in addition to studying the complex atmospheric phenomenon like the jet streams. Unfortunately, Martian atmosphere being so thin will require the envelope of the LTA systems to have 200 times the volume at Earth's surface, such a volume will paralyze operations and reach of the vehicle. A vacuum shell airship might prove feasible. In such an airship partial vacuum is created within the rigid structure instead of filling it with a buoyant lifting gas. It was first envisaged by Francesco de Lana in 1670. Building such an airship is impossible in the thick and heavy atmosphere on Earth as the pressure difference would be as great as 10,000 kg/m², but on Mars, the difference would be as little as 70 kg/m². Being aerial, the airships will be continually subjected to winds thereby preventing sand from choking the PV layers.

MANOEVERING

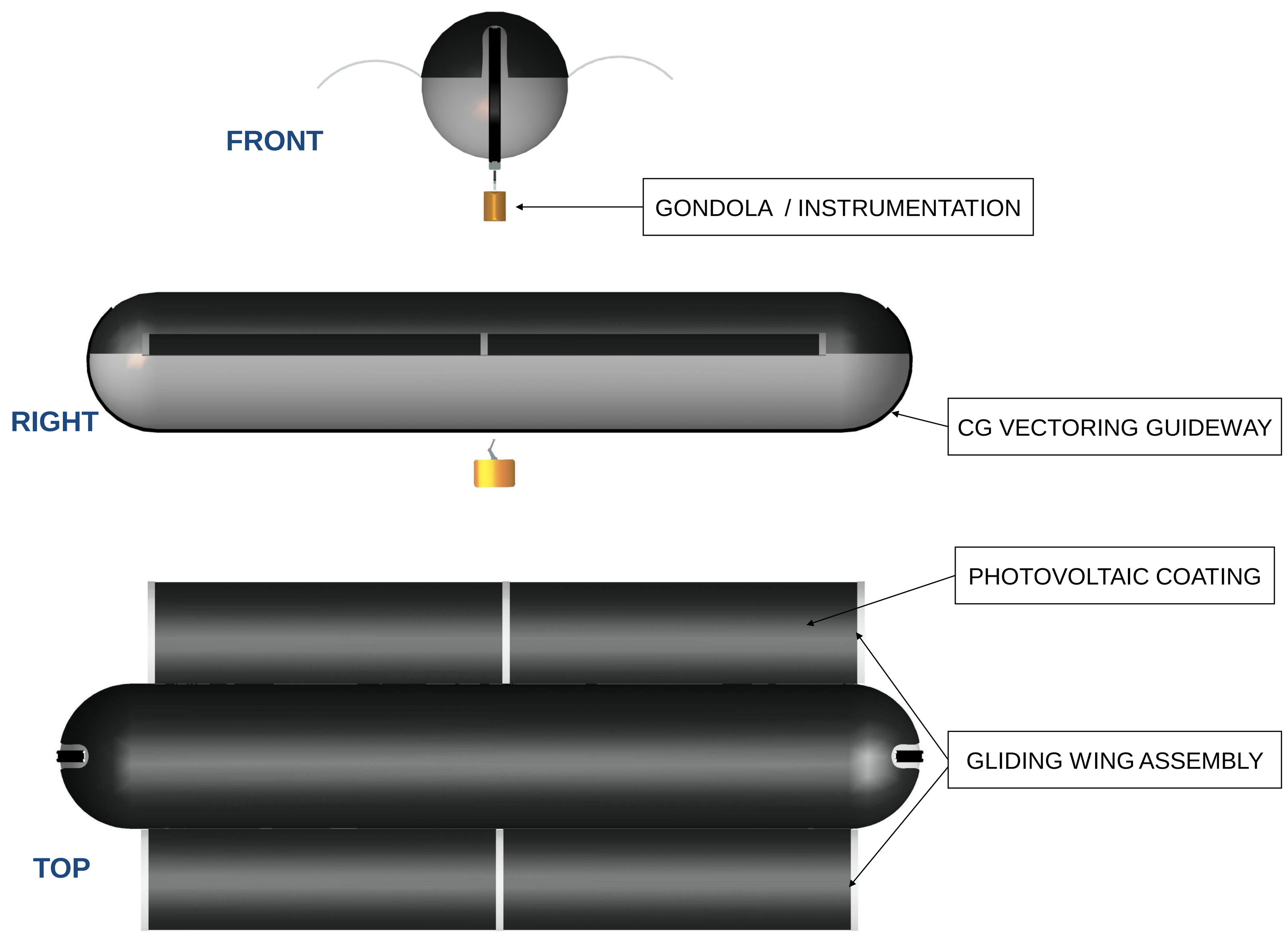
Due to the very low Reynolds Numbers that exist in the Martian atmosphere, the operation of conventional rotary propellers will be inefficient. A novel form of propagation has been envisaged in this case. The airship will gain in altitude by increasing the degree of vacuum within the envelope, then the buoyancy will be reduced by reducing the degree of vacuum. In doing so the airship will glide to a desired destination using its wings. To allow access to cliffs and other crammed places an innovative CG vectoring system has also been envisaged. The combined mechanisms of CG vectoring and glide will work in tandem in order to gain the best aerodynamic advantage and mobility in practically any direction.



LIFT, HOVER, GLIDE & HOVER BY VARYING THE BUOYANCY , CG AND BY USING THE WING ASSEMBLY

STRUCTURE

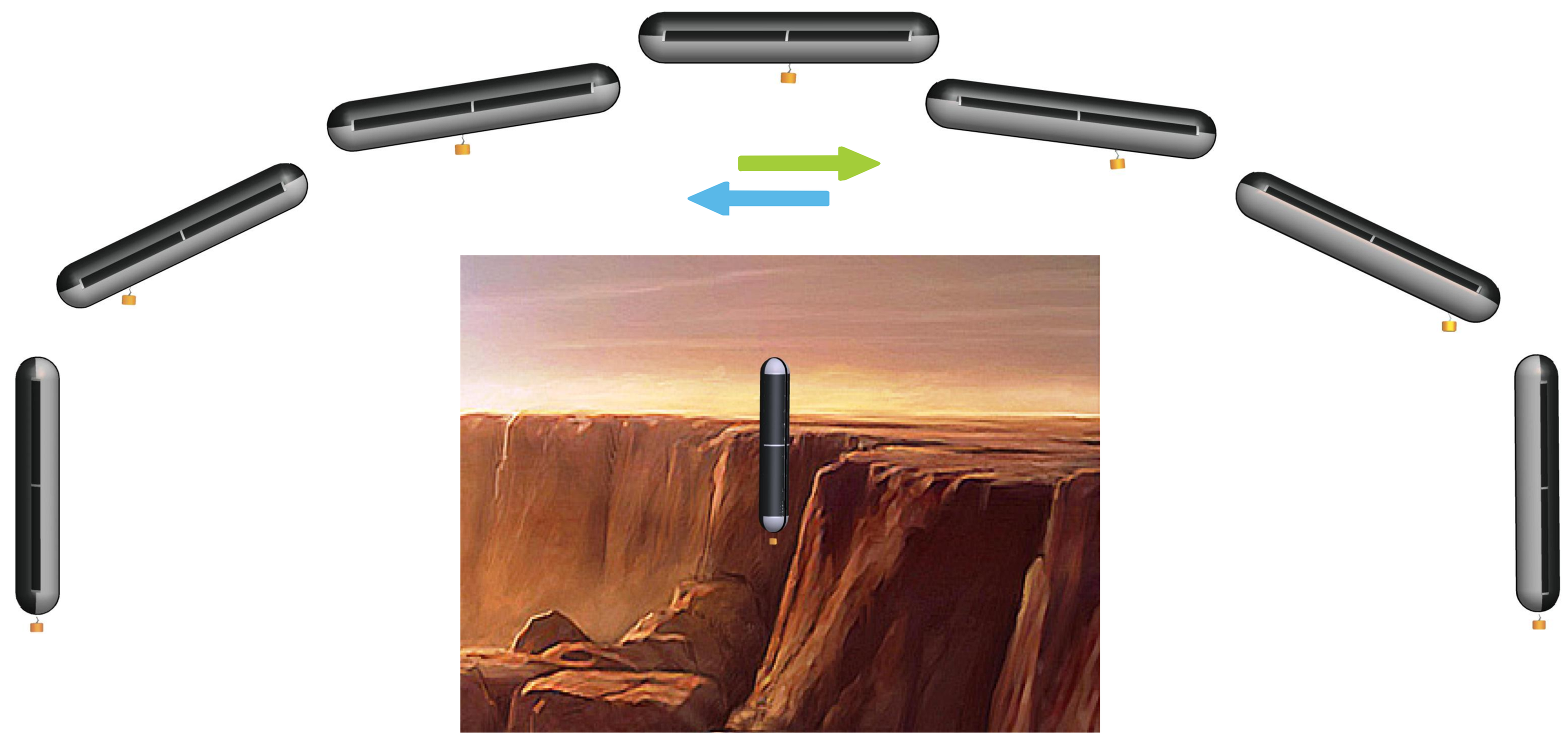
Francesco de Lana in 1670 had suggested using four copper spheres in the vacuum airship. Though the sphere is best at handling such pressures such a shape would greatly increase the aerodynamic drag. A cylinder with hemispherical ends is ideally suited for the task.
The dimensions of the Airship will directly depend on the payload, the available materials and the operation ceiling.
The deployable wing assembly will allow the airship to glide and can be furled in completely to reduce drag in particularly unfavorable weather conditions. The vacuum pump would be housed within the envelope itself.



VARIOUS VIEWS OF THE RIGID VACUUM AIRSHIP

CG VECTORING

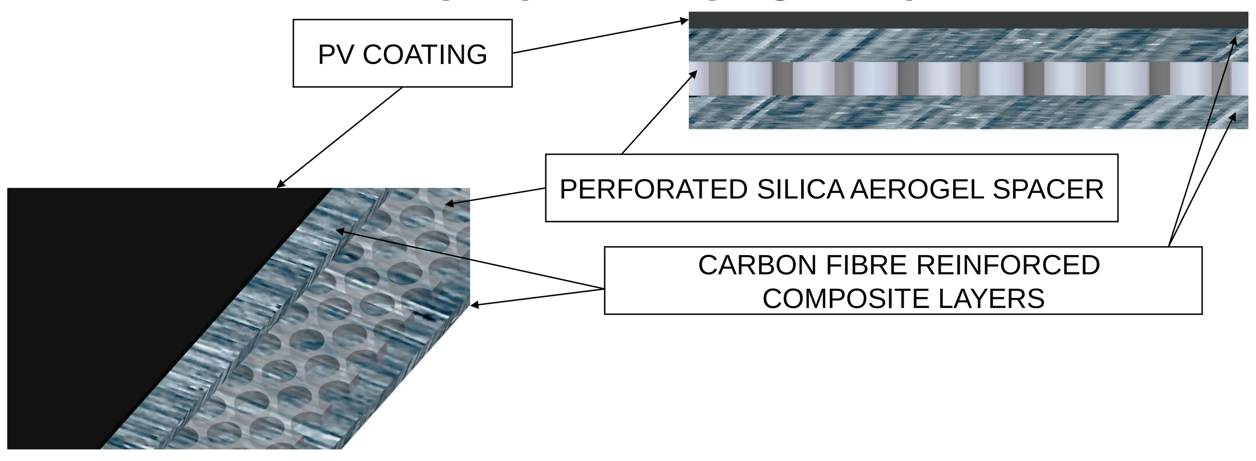
The CG vectoring system allows any degree of inclination for the airship. The rigid envelope being buoyant would have to weigh less than the instruments and the gondola. This feature is particularly useful when rapid gain or loss of altitude or to squeeze into canyons especially for geological study. It would be a seamless integration and would work in tandem with the vacuum pump and the wing assembly.



CG VECTORING ALLOWS ANY INCLINATION OF THE AIRSHIP

MATERIALS

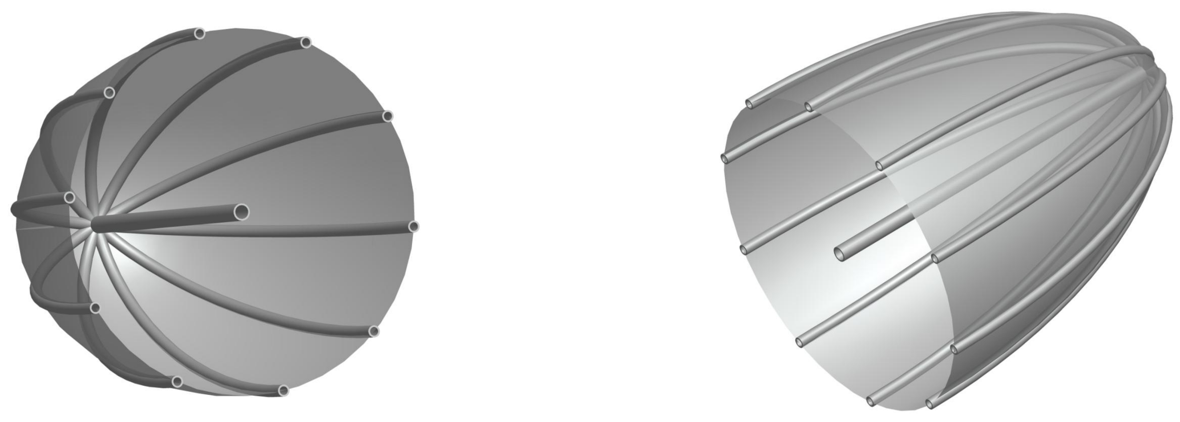
The materials being the key factors will have to be the lightest and the toughest technology provides us. The envisaged material for the envelope is a radiation-hardened composite made from a layer of perforated Silica Aerogel sandwiched between layers of woven Carbon Fiber. In future the availability of woven Carbon Nanotubes would permit greater flexibility and rigidity at still lesser weights. A coating of Thin Film PV with radiation protection finish will provide power instead of the bulky crystalline PV systems. The material is also a good heat insulator and would prevent fluctuations in buoyancy due to day-night temperature shift.



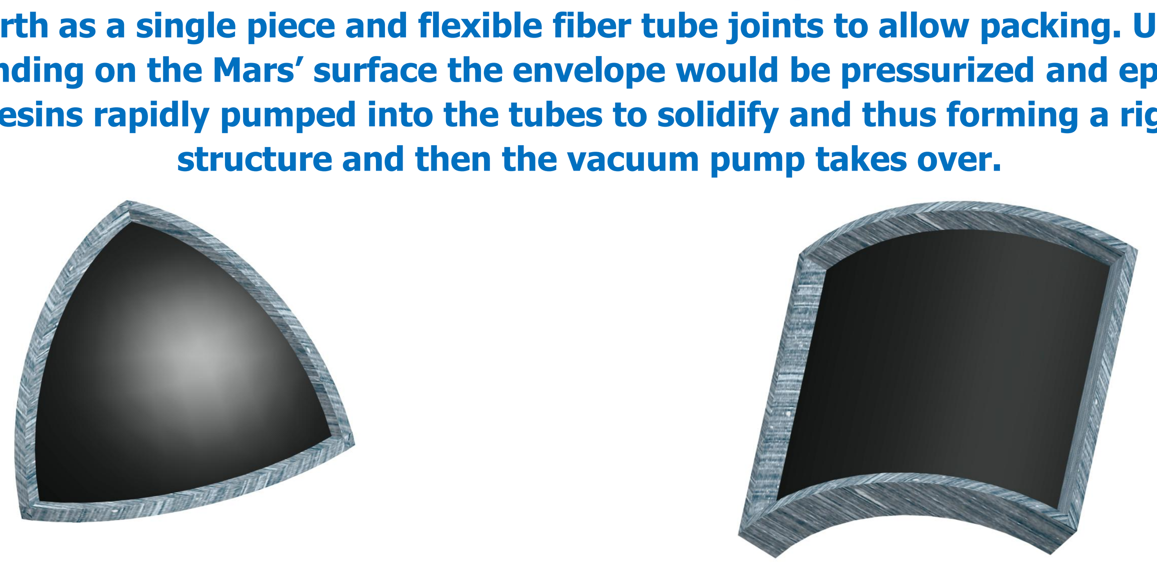
VARIOUS LAYERS OF THE COMPOSITE SANDWICH

ASSEMBLY

If built the Vacuum Airship will be the second largest man-made object in space after the ISS and the largest to explore any other extraterrestrial world. Undoubtedly the structure will have to be assembled on Mars itself. Two major approaches for the assembly have been identified :-



THE INFLATABLE APPROACH: The entire envelope will be fabricated on Earth as a single piece and flexible fiber tube joints to allow packing. Upon landing on the Mars' surface the envelope would be pressurized and epoxy resins rapidly pumped into the tubes to solidify and thus forming a rigid structure and then the vacuum pump takes over.



ROBOTIC ASSEMBLER: The different segments will have to be built, packed and transported to Mars' surface. There an autonomous robot will assemble the different segments to form the final structure. The assembler can later used for maintenance work on the airship.

INSTRUMENTATION AND OPERATION

Apart form the general instruments on board, the Vacuum Airship will require wind speed sensors, gravity measurement devices, valves. It will also require radiation-hardened power PC. Like the rovers, the rovers will need to be autonomous due to the lag in communication time. A deployable tethered geologist could also be incorporated. Apart from the ability to sample different layers of the Martian atmosphere the Rigid Vacuum Airship also provides a relatively stable platform for the instruments with no HF noise. Communications could be direct or relayed via an orbiting satellite. The airship will have to periodically reach the surface to dump the static charge that is built up during operations.

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