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AVIATION ON MARS

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INTRODUCTION

Human beings as Martian explorers will need a variety of tools to do the job. This discussion focuses on one of the assisting technologies – an aircraft.

Pioneers such as the Wright brothers, Glenn Curtiss, Admiral Byrd, and Charles Lindbergh demonstrated that the airplane is the only economically and operationally justified means of long distance transportation when the need is to reduce time.

Time is money, and on Mars, the exploration team's full mission cost can be divided equally amongst the days spent actually exploring. To maximize the return on each budgeted

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exploration dollar, and to get the most work done each day, the Martian exploration team will need to cover a lot of ground. This cannot be done by ground transport.

Ground transportation will play a very major role in the transportation infrastructure of Mars during the exploration phase, and will continue to do so during the development and settlement phases. There are roles, however, that cannot be addressed by using a ground-based system, such as Search and Rescue, parts replacement, reconnaissance, and rapid evacuation.

Further, although UAV's (Unmanned Aerial Vehicles) may also have a definite role in exploring Mars, the Martian aircraft described here are all manned. Too much can go wrong with UAV's and with a typical flight. No computer based reasoning system could in the foreseeable future have the capability of dealing decisively, correctly, and quickly with the range of situations in which failure and destruction would be the outcome. The human being in the loop is a weak euphemism for stating that the human being is the key element in the equation, with the aircraft or vehicle or system there to facilitate the human's presence.

The Mars aircraft at Martian equivalent sea level will be operating in an aerial environment similar to an Earth altitude of between 106,000 and 130,000 feet, depending on how things are measured, including the effects of a reduced gravity. To successfully operate and aircraft at this altitude takes our engineering skills to the limit, but appears feasible. Recent flight experience with the ERAST program and the Pathfinder aircraft by NASA demonstrate clearly that this new domain of flight is in fact manageable.

Five airborne technologies are examined, albeit rather lightly. The five candidates are: fixed wing airplane, rotary wing aircraft, lighter than air (LTA) vehicle, wing assisted rocket plane, and non-aerodynamic rocket platform.

The mission definitions and needs of the explorers will of course be the overriding drivers of the design process. Some of the mission attributes or parameters would be payload, speed, duration, maximum altitude, visibility, landing and takeoff constraints, and field maintainability.

Some common characteristics apply. The fuel system must be completely self contained (all of the necessary chemicals), the vehicle must have a carrying capacity of no less than a crew of two plus two passengers plus survival gear. The vehicle must have an additional cargo carrying capacity of some set value.

Some operational specifications might be: maneuverable amongst the valleys and peaks of Mars, remote landing and takeoff capability, self contained startup and shutdown capability, planetary range, very high and/or very low speed capability.

FIXED WING AIRPLANE

An airplane with low wing loading and low drag can operate in the lower levels of the Martian atmosphere, as shown by simulations in wind tunnels and with software. The aerodynamics of such a configuration are very much dependent on an already refined design. It will resemble a glider, with very high aspect ratio wings for minimal induced drag and a glide ratio of about 40 or 50 to 1. The speed of such a vehicle would not normally be more than about twice that of a normal glider.

This low speed craft would have the advantage of allowing a longer loiter period or dwell time at points of geophysical interest, as well as permitting a fairly close in view, within tens of meters, of what is being observed.

Propulsion would be most efficient with a propeller driven design. The prop would be a large diameter, slowly turning, variable pitch design. This should allow thrust levels and throttle response rates adequate for takeoff and climb rates needed to clear local obstacles.

ROTARY WING AIRCRAFT

This configuration has two major advantages for a Mars exploration mission. Takeoff and landing can be made virtually anywhere, and while hovering, the aircraft will facilitate a detailed inspection of any geographic anomaly. The technical nature of the rotor system may require a contra rotating (two-rotor) blade system called Advancing Blade Concept (ABC). This is a technology with several existing prototype helicopters. The reasoning is as follows: the limiting factors on Mars for forward airspeed are the tip speed of the advancing blade nearing the Martian speed of sound (about .7 of Earth speed of sound) and the stalling of the retreating blade at high angles of attack in thin air. The ABC concept unloads the retreating blade completely, avoiding stall, and by adding extra blades (up to six or seven) the rotor speed can be kept low enough to delay onset of sonic drag conditions.

Range may be limited for a rotating wing aircraft on Mars, but its versatility over a moderate operational radius from base camp will well be worth the tradeoff. Particularly in operations involving spot pickup and drop off, the Martian helicopter will excel at missions such as Search and Rescue, medical evacuation, pinpoint geophysical soil sampling on mountainsides, and emergency delivery of parts or personnel to specific remote positions.

LIGHTER THAN AIR CRAFT (LTA)

The super thin Martian atmosphere will tax the designers of conventional aircraft and rotary wing aircraft, but the LTA concept will push the envelope to its limits. The numbers indicate a potential here, but just so by a small margin. Let us examine some of the numbers to get an idea of the potential.

A cube of air on Earth ten feet on a side has a mass of about 78 pounds at sea level pressure, temperature, and density. It has been commonplace ever since the Montgolfier brothers in France and Count Von Hindenburg in Germany to displace this mass of air with a lighter gas at the same pressure. Hydrogen gas was used until the late 1930’s. It is the lightest of the gases, and at STP (standard sea level temperature and pressure), a ten foot cube will weigh about one fifteenth that of air. So a cube of hydrogen will produce about 73 pounds of lift.

Helium replaced hydrogen as a dirigible gas because it is almost as light, readily available, and in particular, inert. Its weight being about twice that of hydrogen still allows our ten-foot cube to lift almost 70 pounds.

On Mars, with a sea level equivalent pressure of only 0.7 percent that of Earth, a ten foot cube of hydrogen would weigh about seven one thousandths as much as on Earth, or about 3.5 thousandths of a pound. But even the Martian atmosphere, at a near vacuum, only weighs in at about a tenth of a pound. So the net difference in weight would be about ninety-six and a half thousandths of a pound. This means that to get a full 73 pounds of lift, we would need about 760 such cubes. Fortunately, Martian gravity is only thirty seven percent that of Earth. So we need even fewer cubes, about 280 cubes.

So to carry the same payload on Mars as on Earth we are looking at a design that begins almost 300 times as large as a similar vehicle on Earth. This sounds extreme, but amounts to a cube of hydrogen on Mars of 67 feet on a side producing our net 27 pounds of lift.

Ignoring such pesky add-ons such as structural weight, a dirigible made to lift one person of 200 Earth pounds, or 74 Martian pounds, would need about three Mars-sized cubes for lift. Four people would need a dozen, plus another dozen for payload, and another couple of dozen for fuel and structure. This means a spherical balloon would need to hold almost 50 volumes of a third of a million cubic feet each to be useful. A dirigible of 17 million cubic feet is called for, about triple the size of the Hindenburg.

A design that could be more optimal is that of a parasail, with an arc some 470 feet across, a chord of about 140 feet, and 40 feet thick. The lifting volume would be the same, but the operational flexibility in terms of its ability to maneuver, be segmented into sections easily pumped down and inflated again, and modular construction may make this option an aerial transport vehicle of choice.

ROCKET POWERED AIRCRAFT

The Martian atmospheric environment resembles closely the regime in our upper atmosphere in which a good many flight records have already been set. Chuck Yeager's flight at fast than the speed of sound and Scott Crossfield's flight in the Bell X2 at twice the speed of sound were done at extreme altitudes. Scott's flights in the X-15 were at impressively higher altitudes, up in the 250,000-foot range. Clearly we have the precursor aircraft already built.

This type of vehicle is the optimum choice where speed is of utmost importance in reaching the destination. With suitable tankage, range could be virtually the entire planet. The wings provide the lift, and the rockets the thrust. Being a winged vehicle, it can be highly maneuverable for doing a complex reconnaissance mission at high speed and altitude.

Although capable of self-contained startup, take off, landing, and shutdown, the constraints imposed on the concept are dominated by the need for extensively prepared runway surfaces from which to operate. A booster could be used for takeoff, but the landing would still have to be somewhat conventional.

ROCKET LANDER

This is a glorified Lunar Lander design, with little or no atmospheric or aerodynamic effects taken into operational account. Range is potentially quite considerable, but limited to point to point, with little side trips or excursions not feasible. Course corrections would be of course minimal.

Response time could be quite fast. The technology used is primitive but reliable. When the landing point is known specifically, the payload and fuel are loaded appropriately. A substantial portion of the flight is in ballistic mode. A booster at base camp could help with heavier payload or fuel loads. Although Search and Rescue operations could be conducted with this vehicle, the location of the party to be picked up would have to be a known quantity.

In the context of the Martian atmosphere and planet, it could be seen to be a part of a surface to orbit infrastructure.

CONCLUSION

All five of these systems offer a defined envelope of operational constraints and characteristics that may be optimal for various mission needs. Ultimately, vehicles for use on Mars will undoubtedly be of a variety of designs, just as conventional Earth based aerosystems are designed one quite differently from the other to meet specialized needs.

It is probably within the capability of individuals or small interest groups to undertake the design and construction of one or more prototypes of these aerial vehicles. Although the Earth and Martian atmosphere differ considerably, it should be possible to verify proof of concept of one or more of these design approaches by conducting analogous flight operations.

However the initial aerial transport services are approached on Mars, they will be defined by the needs of the explorers, developers, and settlers. It is very likely that one or more of these five approaches will be adapted to aerial transport on Mars.