Mars Aerial Vehicle – Rocket Intraplanetary Carrier

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abstract: In 2004, President Bush outlined the United States’ Vision for Space Exploration (VSE). The overall objectives of the VSE is to begin an exploration campaign to return safely to the moon, sustain a U.S. presence on the moon, and begin human exploration of Mars. Several trips will be undertaken to further explore the surface of Mars to identify places suitable for continued human presence. As the Mars exploration campaign continues to expand, habitats will be scattered around the surface for continued Mars surface exploration progression. More scientists and engineers are arriving on the planet, slowly developing a continued human presence on Mars with the only transportation capability being either manned or robotic rovers. This capability limits the ability of the new inhabitants to explore the surface of Mars at farther distances from their outposts. Therefore, there is a need for a vehicle capable of delivering personnel and cargo at distances beyond the capabilities of conventional rovers. This vehicle is no ordinary vehicle. The Mars Aerial Vehicle – Rocket Intraplanetary Carrier (MAVRIC) design integrates a liquid oxygen/liquid methane rocket engine with an inflatable swept wing to provide practical transportation to deliver personnel and cargo to destinations that are over 4 times the distance conventional rovers could potentially travel.

Introduction

The goal and objective of the MAVRIC system design is to provide a rapid delivery capability for continued Mars exploration. A review of the Apollo lunar rover showed that over the three missions (Apollo 15, 16, and 17) the lunar rover vehicle traveled a maximum of 35.9 km in 4 hours and 26 minutes (on Apollo 17) with the longest traverse being 20.1 km (again Apollo 17) and a maximum range from the Lunar Excursion Module being 7.6 km (Apollo 17) (Reference 1). With a sustained human presence on Mars being discussed with the President’s Vision for Space Exploration, Mars astronauts will be required to traverse the Martian terrain at further distances than those of the Apollo astronauts to explore vast areas of the planet.

Mission Infrastructure

By the time the MAVRIC vehicle is operational, Mars surface exploration will be well underway. It is assumed that many habitats are scattered short distances that are practical for the use of rovers.

These habitats have a central command headquarters that houses the overall integration function of the exploration effort. Adjacent to this headquarters is a LOX/CH4 in-situ resource utilization (ISRU) plant to provide needed propellant capability for continued Mars surface operations.

A global satellite communication network is beginning to be established. This network allows for ease of communication anywhere on the planet. These satellites aid in navigation similar to the Global Positioning System (GPS) on Earth.

For ease of recharging batteries solar arrays and possible nuclear reactors will be present for powering the habitats and the Rovers.
The Need

With a sustained human presence on Mars, exploration will continue to expand across the surface. To traverse farther distances from habitats a need exists for a vehicle to deliver personnel and cargo to these farther distances. A literature review revealed that the maximum speed of the lunar rover design was 13 km/hr. Assuming that a Mars explorer has only 8 hours of oxygen within his/her spacesuit, the maximum distance that a rover could deliver personnel/cargo is 45.5 km. This distance does not include any time to explore the area or unload cargo. Therefore a vehicle is needed to provide a rapid transit time to destinations of interest for the explorers. This vehicle could also provide for an emergency capability to rescue an ailing explorer.

Vehicle Requirements

To meet the need of a vehicle capable of delivering personnel and cargo vast distances some basic requirements were levied on the MAVRIC system design. Of utmost importance was the vehicle’s ability to travel at least four times the distance of a conventional rover, approximately 120km. Secondly the volume of the vehicle could not exceed the volume of the Cargo Launch Vehicle (CaLV) shroud (assumed to be the largest 5 m shroud in the Delta-IV fleet), about 630 m$^3$. The payload delivery capability was defined to be 185 kg. This mass is equivalent to one pilot and two passengers. The vehicle has to make use of Mars surface ISRU for engine propellant. Upon arrival at the Mars surface, minimal assembly is required to alleviate the need for extensive tooling requirements.

To allow for operations around the surface of Mars, the vehicle was required to have a maximum take off and landing distance of 0.5 km. This requirement would allow the MAVRIC to be used on less than pristine launch/landing areas. The vehicle structure was designed to survive a 10g hard landing. The vehicle was designed to have an operational lifetime of 2 years, assuming one trip per week. For the most part the vehicle must be autonomous, but in special cases a pilot needs to be able to operate it manually.

Operational Concept

The MAVRIC will be manufactured and assembled on Earth into its component pieces. All the necessary parts will be assembled, i.e. the propulsion system, the fuselage. For redundancy, extra parts will be sent along for regular and extensive repairs. Final packaging is completed and the MAVRIC is launched from Earth to arrive at Mars.

The MAVRIC will be rolled out of the cargo container once it arrives on the surface of Mars. A thorough inspection is completed to ensure no damage has occurred during shipment from Earth. If any component on the MAVRIC is broken, it will be replaced with the replacement parts. When the system passes inspection, the MAVRIC is then rolled out to allow the wings to be inflated. The inflated wings use the UV rays to help cure the material to make them rigid. After allowing the wings to set, the MAVRIC is rolled back to let all the components acclimate.

The mission of the MAVRIC depends on the amount of oxygen available for each crew member. It is assumed that each explorer has eight hours of oxygen available for use, one hour for reserve and seven hours for flight time and scientific research.

A typical flight day consists of the initial systems check. This check includes a computer diagnostic of all the operational systems. Also the check includes the same manual check performed on aircraft here on Earth. While the check is being performed
all the tanks are filled with fuel, oxidizer and pressurizing gases. Right before flight all the oxygen tanks for the crew members are filled for maximizing time away from base camp. The MAVRIC is fired up and takes off from base camp for the specified location. The amount of time for flight is less than 30 minutes for a range of 140 km.

The MAVRIC arrives at its destination giving the crew members roughly four to five hours of research time. The system diagnostic before flight takes another forty-five minutes, and right before it is time for this check mission control will contact the crew members to prepare for departure back to base. The check will then be preformed and the MAVRIC returns to base camp with in the time span of the oxygen tanks.

Upon arrival a final check of the MAVRIC is completed. This is to ensure nothing is broken and it will be placed in storage for its next mission.

The capabilities of the MAVRIC do not end on scientific missions. Depending on what is needed from mission control determines the desired mission. The MAVRIC can be a research vessel. It can take cargo from camp to camp when supplies come in from Earth. The MAVRIC can also rescue an injured or stranded crew member is a reasonable amount of time.

**Detailed Design**

**Atmospheric Conditions**

To keep all the calculations consistent throughout the group the atmospheric conditions of the planet are a starting point. The values used for Mars’ atmosphere are detailed in Table 1.

<table>
<thead>
<tr>
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<th>Initial (kg)</th>
<th>Final (kg)</th>
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<tbody>
<tr>
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<td>625</td>
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<tr>
<td>Propulsion</td>
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<tr>
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<tr>
<td>Total</td>
<td>1500</td>
<td>6006</td>
</tr>
</tbody>
</table>

**Propulsion**

The propulsion system is an integrated system providing not only force for altitude and downrange capability (main propulsion) but also for attitude control purposes (reaction control system) as shown in Figure 1. The entire system utilizes a LOX/CH4 propellant combination that is provided by an ISRU plant which is located on the planet’s surface.
The main propulsion system consists of a main engine, one fuel tank, two oxidizer tanks, and one high pressure helium tank. The main engine is offset 6 degrees from the vertical location of the vehicle center of gravity to allow for forward motion as well as vertical flight. A concept with two engines performing these functions was evaluated and was determined to be more massive than one engine with a higher initial thrust.

Engine trades were performed to determine the correct thrust profile needed to achieve the downrange requirement of 120 km. Working with the aerodynamics subsystem (the wing), a trade study was performed to determine the appropriate needed thrust profile. The main propulsion system was assumed to fire for the first five minutes of the flight and then allow the aerodynamic surfaces to control the vehicle descent to a distance of at least 120 km. Figure 2 depicts the thrust profile determined to meet the requirements for the departure portion of the mission and the return portion.

![Figure 2 – Engine Thrust Profile](image)

All reaction control jets will utilize a propellant combination of LOX/CH4 for oxidizer and fuel and will be able to deliver 445 N of thrust. The 445 N RCS jets will provide adequate torque levels for the MAVRIC during main engine firing and while the vehicle is gliding. Figure 4 shows a LOX/CH4 reaction control jet.

The attitude-control method selected for the MAVRIC was a reaction control system (RCS). RCS is commonly used for flight at extremely low dynamic pressures. RCS utilizes the reaction forces developed by small-rocket units located on the vehicle to produce rolling, pitching, and yawing moments. Twenty-four reaction control jets will be used for attitude control on MAVRIC. Three-axis control capability will be available because of the distribution of the twenty-four jets. Figure 3 shows a schematic representation of the control system.

![Figure 3 - Conceptual Image of (RCS) jet arrangement](image)

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The design of MAVRIC RCS followed the following steps. The total impulse required for the reaction control jets was analyzed. Any disturbance torques on the vehicle was located to determine the magnitude, accuracy, and type of thrusting...
maneuver to perform. The MAVRIC will have two modes of flight autonomous/manual. The RCS jets on MAVRIC in autonomous mode will be controlled by a digital controller embedded into the vehicle systems. The systems will monitor the vehicles orientation and issue the proper inputs to the reaction control system to provide the necessary torques to position the aircraft. The reaction control system in manual mode will receive commands from a human pilot.

Aerodynamics

The shape of the wing for the MAVRIC evolved from a short stubby wing shape to a long slender wing shape as in Figure 5. Reasons for changing the shape of the wing are because the packaging of the wings is not an issue since an inflatable material was chosen and also the aspect ratio of the previous configuration was very low for the flight conditions. This swept wing has a wing span of 60 meters, a five meter and two meter root and tip chord, respectively. The aspect ratio of the aircraft is eighteen. This value is typically good for a glider; most gliders range from 20 +/- 4 or 5.

![Figure 5 – Wing Geometry](image)

The airfoil chosen for final analysis is the NACA 8318. The most logical reason this airfoil was picked is it is already available from the inflatable wing manufacturer to be put on an airplane. This thick high cambered airfoil, usually used for high altitudes, helps the MAVRIC to fly in atmospheric conditions similar found on Earth and also allows for flight at lower angles of attack. Other airfoils evaluated would give lift coefficients known for stalling at the set flight conditions making them unsuitable for further examination. Initially, the MAVRIC utilized an attitude control system to adjust for the majority of the control maneuvers for the vehicle; this includes maintaining a static stability, in addition to yaw, pitch, and roll capabilities during flight. For a design change the majority of the system incorporates ACS to maneuver the MAVRIC, for static stability a tail was added to keep the vehicle level during flight. The tail is the same shape as the wing, scaled down by a factor of ten. The airfoil used for the tail is a NACA 0012. A majority of aircraft use a symmetrical tail so it does not add a positive moment causing the aircraft to pitch up. The tail is located approximately fifteen meters behind the center of gravity of the aircraft.

Landing Systems

The MAVRIC landing system comprises all the required components necessary to bring the vehicle to rest safely by absorbing the impact energy from landing. The required systems for landing include: suspension and necessary braking mechanisms to bring the vehicle to a complete stop. The baseline requirement for the landing system states that the vehicle will come to a complete stop within 500m of touchdown, and have the ability to survive the brunt impact of a ten-g landing at a maximum approach velocity of 100m/s. The design of the landing system on the MAVRIC meets and/or exceeds all baseline requirements.

The Landing system for the MAVRIC consists of four separate non-retractable landing gear assemblies. The design of each assembly (shown in Figure 6) consists of the following: Vertical Loading Component, Spring-Damper system, Braking System, Horizontal Loading Component (a.k.a. Trailing Arm) and Wheel Bearing assembly that meets the MAVRIC maximum lifetime.
requirement of 1050 landings. The maximum lifetime is determined for 5 trips per week for 2 years.

One of the main features of the MAVRIC’s landing system is the very long vertical loading component. This design was chosen in order to account for maximum stability upon landing. Maximum stability of MAVRIC is needed to account for the very large wingspan which prevents the vehicle from tipping during a landing event.

The vertical landing component is designed to absorb all of the vertical forces during landing. The final design of this component utilizes the advantage of a modified cross-section to better attenuate the stresses seen during a hard landing. The material for the part was chosen as 7075-T6 Aluminum due to its high strength to weight relationship. The length of the vertical landing component was determined to be 1.524m long with the spring acting at a point 0.518m from the wheel/spindle connection. Modified cross-section for the vertical load component can be seen in Figure 7.

The landing system was designed around a predetermined geometry to maintain maximum stability of the MAVRIC during a ten-g hard landing event. With the predetermined geometry various spring damper systems were analyzed to determine boundary conditions. The final design on each assembly incorporates a coil spring with a spring rate of 87.6kN/m and a Damper Rate of 35kN*sec/m. with the spring damper system determined a simulation comparing a one-g steady loading with a ten-g steady loading was performed as seen in Figure 8. This response analysis establishes the upper and lower design margins for the landing system.
The Braking System for the MAVRIC is required to bring the entire vehicle to a complete stop within 500m with an approach velocity of 100m/s. The major component in brake design is the ability to overcome the torque placed on the wheels during landing. Another major component in brake design is the heat created from landing. The temperature rise can be found by considering that the brakes absorb all of the kinetic energy of the vehicle during landing. Another design feature of the MAVRIC’s brakes incorporates a bias of 64.6% front and 35.3% rear. This accommodates for the forward weight shift of the vehicle under braking. The analysis done for the MAVRIC assumes a constant pressure gradient to each front and rear brakes. The torque generated by the front and rear brakes are compared throughout the pressure gradient and can be seen in Figure 9.

![Torque Exerted on Brake Element](image)

**Figure 9 - Brake Torque vs. Pressure Gradient**

In order to bias the brakes smaller brakes were used on the rear. The brakes in the MAVRIC are design with a disc style design that incorporates a central cooling passage to allow convection heat transfer with the cold Mars atmosphere.

In the final design of the brakes the Factor of Safety margin is 2.514 which provide ample needed stopping power in an emergency situation if necessary. The disc design for the front uses a 17 inch rotor while the rear brakes incorporate a 12inch rotor on each wheel. The material for the brakes is Aluminum because of its ability to dissipate heat rapidly. In the final design the temperature rise in the brakes under a 100m/s landing in 500m is 315K for the front brakes and 327K for the rear brakes. This is a very reasonable temperature range since Aluminum melts near 900K.

Also incorporated with the suspension design is the Horizontal Load Bearing Suspension Component also referred to as the Trailing Arm. The forces seen in the Trailing Arm is strictly related to the vehicles ability to stop. Because of the way that the landing system is designed the Trailing arm only absorbs the horizontal force components of landing. The trailing arm was predetermined to be placed at 45 deg connecting the wheel/spindle to the fuselage in order to minimize forces and length. The force was calculated by using the independent braking forces on each element. The Material determined for use in the construction of the Trailing Arm is the same as the Vertical Load Bearing Component Aluminum 7075-T6. The Trailing Arm is a tubular member with a outside diameter of 0.017m and an inside diameter of 0.011m a nd a length of 2.115m. With these parameters the trailing arm has a Factor of Safety of 4.153.

The wheel bearings for the MAVRIC are designed to withstand the life of the vehicle with a launch 5 times a week for 2 years. With this timeline it equates to roughly 1050 landings in 2 years. The bearings were selected for MAVRIC using a technique outlined in the book “Fundamentals of Machine Component Design” by Robert C. Juvinall and Kurt M. Marshek (3).
bearing is designed with 95% reliability and design to meet the Life requirement of MAVRIC. Also the bearings are “doubled up” on each spindle 8 total. The Bearings are a Medium 300 Series Basic Bearing # 309.

Structure

The ribs for the fuselage were designed using Aluminum 7075 considering that this material has a high tensile strength and a low density. The main components of the fuselage are nine I shaped circular elements, one meter spaced. These elements maintain the shape of the body skin and provide supports for the longitudinal shell stingers. The first eight rings also support the bending and torsion moments developed by the wings.

The stringers are also designed with Aluminum 7075 and have a C shape cross section. For the stress calculations the stringers have been considered as continuous beams. The fuselage is non-pressurized with minimum external forces acting upon it was determined that sixteen stringers were required for the fuselage.

The material selected for the skin of the fuselage is a Kevlar/epoxy composite, 2.5 mm thick, including a protective polyester layer to mitigate UV damage. The properties that make this material suitable for this project are its low density, high specific strength (ten times stronger than aluminum) and high impact resistance, among other important characteristics.

One of the distinctive features of the MAVRIC is its use of inflatable wings as its lifting surfaces. This selection was done considering the mass and volume constraints of the mission, which are achieved with this type of wing. The wings primarily consist of vectran which is a high strength liquid crystal polymer with exceptional performance properties for inflatable wings. The wings will be cured and consolidated by Ultra Violet Radiation on site. Basic stress analyses for the MAV-RIC wings were done using Ideas-10 FEA software. Figure 10 shows the Finite Element Analysis for one of the wings. The preliminary analysis on the wing shows that a 4.5 mm thickness of rigidized vectran will support the drags and lifting loads acting on the wing surfaces.

![Figure 10 – FEA of Inflatable Wing](image)

Power System

A rechargeable advanced Lithium-Ion battery will be used for the MAVRIC power system. The decision to use an advanced Lithium-Ion battery was based on the tremendous success of the batteries on the Mars Exploration Rovers. The power requirement of MAVRIC during its baseline flight time was determined to be 6.9 kW which yielded a Lithium-Ion battery mass of 79 kg. The rechargeable Lithium-Ion battery will supply electric current to the electrical system.

Figure 11 shows an overview of basic components of the MAVRIC Electrical System.
Electrical System

- Lithium-Ion Battery
- Circuit Breakers
- Bus Bar
- Ammeter

Figure 11 – MAVRIC Electric System

The Advanced Lithium-Ion battery will have the capability to produce a sufficient amount of electrical current to operate the entire electrical system. The Advanced Lithium-Ion battery will be rechargeable, which will enable it to recharge when the vehicle is not in use. The Ground Power Units (GPU) will recharge the batteries. The GPU’s will likely be a solar array or other electrical resources available to Mars surface exploration crew members.

A bus bar will be used in MAVRIC as a terminal in the vehicles electrical system to connect the main electrical system to the equipment using electricity as a source of power. This will simplify the wiring system and provides a common point from which voltage can be distributed throughout the system. An ammeter will be used to monitor the performance of the vehicles electrical system. Circuit breakers will be used in the electrical system to protect the circuits and equipment from electrical overload. Circuit breakers will be used because they can be manually reset, rather than replaced if an overload condition occurs in the electrical system.

Crew/Cargo Support

The MAVRIC will be completely autonomous but will have the ability to be operated by manual control. The MAVRIC is designed with a flight computer that is well-suited for ease of use and reliability. The flight computer will be in command of inner controllers that perform the most basic functions such as stabilizing the aircraft. Embedded inside its flight computer will be software suites that govern the vehicle. Each major task for MAVRIC will have programs designed to cover any foreseeable contingency. A hierarchy of the Vehicle Flight Computer is listed below in Figure 12.

Figure 12 – Vehicle Flight Computer Hierarchy

The Systems Controller (SC) is the overall controller of the system. It maintains information on the present state of the vehicle by performing system diagnostics and contains the history of the vehicle by maintaining a log book. The planner will propose a method to execute the mission by analyzing the information inputted into the computer by the crew, the crew will enter certain mission critical information and the planner will configure and assist in executing the mission. The Vehicle Status (VS) will be monitored by a suite of sensors that are used by various modules to perform checks and ascertain the state of various subsystems. The flight mode of the vehicle can be toggled to either autonomous to manual control at anytime of vehicle operation. The vehicle will navigate by use of a Mars Global Positioning System (MGPS). The Trajectory Controller (TC)
that will function in conjunction with the MGPS plans and executes the flight trajectory. In autonomous mode the TC will govern the throttle position of the primary LOX/CH4 during assent. The TC will operate collectively with the Reaction Control System (RCS) as well as the Position Control System (PCS). During autonomous flight the flight computer will direct the RCS to maintain a stable flight and will also coordinates with commands that are generated by the Position Control System. The Position Control System (PCS) is a flight control system to control precision maneuvers. The PCS will work jointly with a sensor suite containing inertial sensors for flight stabilization and navigation sensors for maneuvering the MAVRIC to its designated site.

Modular payload containers that are designed to safely transport 100 lbs will be incorporated into the payload compartment of MAVRIC. The cargo containers are designed so that two crew members will be able to carry and share the load of 45 kg. Each container will be positioned into place on a rack system and will be properly secured with the use tie down straps. The rack system, Figure 13, is attached to points in the vehicle into the structure of the vehicle.

For varying mission scenarios, the payload containers can be supplemented with seats for the traveling crew members as shown in Figure 14. Each seat that is located in the payload compartment can be configured into various forms for emergency scenarios. The crew seats can be rapidly converted into stretchers for injured crew members. Mounting points that are embedded into the rack system will provide the configurable seating with proper anchorage for crew in sitting position as well as those who may require a stretcher.

![Figure 13 – The Rack System](image)

**Figure 13 – The Rack System**

Vehicle Performance

The vehicle performance depends upon both of the aerodynamics of the system and the imparting velocity, altitude, and distance the propulsion system is able to propel the vehicle. From the propulsion system for both the departure and return missions leave the glider with a forward velocity of approximately 100 m/s. With these parameters coefficients of lift and drag are obtained. Table 3 shows the corresponding lift and drag coefficients for the departure and return missions. Though the lift values are high, the weight of the system is the driving factor.

![Figure 14 – Crew Member Seat](image)

**Figure 14 – Crew Member Seat**

**Table 3 – Aerodynamic Coefficients**

<table>
<thead>
<tr>
<th></th>
<th>Departure</th>
<th>Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>(C_L)</td>
<td>2.088</td>
<td>1.788</td>
</tr>
<tr>
<td>(C_D)</td>
<td>0.147</td>
<td>0.105</td>
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</table>
The mission profile as in, Figure 15, shows the beginning of the launch, launching the MAVRIC to the desired altitude, to where the engines shut off and the MAVRIC glides down to its final destination. The baseline requirement was to meet the minimum distance of 120 km. To minimize the propulsion system mass the majority of the distance traveled is accomplished during the gliding phase of the mission.

From both the aerodynamic figures and the velocity from the propulsion system the MAVRIC is able to surpass the preset goal of 120 km. The departure trip is the most massive portion of the mission, with the idea being that if the MAVRIC can meet the requirements on this portion of the mission it should be able to achieve and even surpass the requirement on the return portion of the mission.

In Table 4, it is shown that the distance traveled by both portions exceeds the requirement. The propulsion aerodynamic trade maximized the distance traveled for the departure portion enabling the MAVRIC to glide 138 km. On the return mission the MAVRIC had less mass due to half of the propellant load being expelled allowing for a further distance to be traveled, 169 km. This distance is greater than what is necessary but as stated in the propulsion section the engine is throttle capable allowing for adjustments to be made to arrive safely back at the habitats. Although the MAVRIC is traveling at high altitudes it is able to maintain its velocity practically until it lands safely on the ground. This allows for a softer landing for the landing system making the flight smoother.

<table>
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<tbody>
<tr>
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<tr>
<td>Landing Velocity</td>
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<td><strong>Total</strong></td>
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**Schedule**

Due to the nature of the MAVRIC mission, the vehicle will not be needed for deployment to the surface of Mars until there is a sustained human presence on the Mars surface. With the VSE outlining lunar exploration for the 2020s, initial Mars exploration for the 2030s, and sustained Mars exploration for the 2040s, the MAVRIC is not envisioned to be needed until the year 2050.

With that assumption, the authority to proceed with the vehicle would be granted in 2046 with a total design schedule of approximately four years. The pre phase A (concept studies) would consume six months of the design schedule outlining alternatives to the concept described in this paper. Phase A would last nine months to fully explore the trade space of the concept to further refine the system. Phase B (preliminary design) would last twelve months and phase C (final design) would last fifteen months. Both of these phases are scheduled to last longer due to design requirements for a manned vehicle needing further refinement. Phase D (fabrication, assembly, and test)
would last approximately six months. With this schedule in place, the MAVRIC could be ready to ship to the surface of Mars in 2050. Assuming a trip time of one year, the first flight of the vehicle would be in 2051.

Budget
Using the above schedule and making assumptions about the maturity of the technologies needed for this vehicle (assumed to be TRL of 6.0), a cost estimate of $871.2 million (SFY04) was developed. The cost model used (from UAH Ph.D. student who works for NASA HQ) primary inputs of total system mass, power requirements, and vehicle type. The total cost included the design and development of the vehicle as well as the first flight vehicle.

Cost/Benefit Analysis
With the above budget for developing the MAVRIC system, a cursory cost/benefit analysis was performed to determine the feasibility of developing the MAVRIC system. Using the assumption of eight hours of oxygen for a Mars explorer with one hour for reserve and seven for transport and exploration, a comparison was made between the MAVRIC and a conventional rover.

Adjusting the cost of the lunar rover ($38M in SFY62 vs. $295M in SFY04) and assuming a top speed of 13 km/hr, the MAVRIC provides an exploration capability of greater than three times that of a conventional rover at less than three times the cost. Comparing the MAVRIC to the rover shows that surface exploration time is greater at farther distances from the Mars habitat. Assuming five hours of exploration (which is the MAVRIC mission baseline), the rover can travel a distance of just 13.5 km while the MAVRIC can travel a distance of greater than 140 km.

Education and Public Outreach
The MAVRIC design team was integrated with the overall UAH Integrated Product Team design course. As a part of that course, an open house was held, allowing the different design teams the opportunity to present their ideas to the campus and local community. At the end of the IPT course a banquet was held where local government, industry, and academia heard the proposed design concepts from each team. The MAVRIC team presented its design at this banquet.

To further the educational outreach of this design, the MAVRIC team spoke at a symposium at the U.S. Space and Rocket Center’s Space Camp as shown in Figure 16. An international audience of high school students learned about the MAVRIC design concept as well as careers in aerospace, NASA’s vision for space exploration, and the overall spacecraft vehicle design process.

Conclusion
The integrated MAVRIC design as shown in Figure 17 demonstrates the feasibility of a rocket-powered glider for continued manned exploration of the surface of Mars. This vehicle provides an increased exploration capability over conventional rovers. Although this MAVRIC design does meet the system requirements, further refinements to the design should be undertaken to fully optimize the design.
Figure 17 – The MAVRIC Design
References