DESIGN AND REFERENCE DOCUMENT: JANUARY 31, 2005

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1.0 MarsFlight Overview/Introduction

NASA has announced a Vision for Space Exploration that will take us to the Moon, Mars, and beyond. To excite students about the vision and the Aeronautics Research Mission Directorate's role, NASA Glenn Research Center's Educational Programs Office submits this design for an immersive and interactive simulation of a remotely controlled airplane that will fly on Mars.

1.1 Idea

The scenario described in this document challenges users to interactively test and/or autonomously fly the Mars Airplane at a user-defined region near the surface of Mars in order to acquire research data on the magnetic field over the area that they fly. Since the Mars Airplane is an unpiloted vehicle, our scenario will place users in front of a control console at the NASA laboratory used to pilot the craft and collect data from it.,

During the Interactive Flight, users will be able to control the flight path of the airplane using a joystick. During the Autonomous mission, users will set waypoints on a graph and the Mars Airplane will attempt to automatically follow this user-selected path while data is collected. The speed of the vehicle can be interactively controlled during either mission.

An optional component will enable two users to work cooperatively to guide the craft, to control the engines, and to operate the radio transmitter in order to obtain the greatest amount of data before fuel, batteries, or time runs out.

Since the atmosphere of Mars is thin, earth-bound scientists have to pay special attention to the atmospheric density when determining which areas support better, and more stable flight. MarsFlight will enable users to determine their best flight path to conduct scientific research on Mars by monitoring and displaying the atmospheric density of the user-defined region where they fly.

This scenario will involve an educational component of data acquisition and graphing, an interactive component of real-time flight testing in Virtual Reality, and an actual flight on Mars utilizing waypoints that are selected by the user.

While we are working very closely with the NASA Aeronautics Research Mission Directorate in the development of airplanes for Mars and other planetary missions, ARES (Aerial Regional-scale Environmental Survey of Mars) was conceived, designed, and developed by the NASA Langley Research Center. In 2002, the ARES mission proposal was submitted to the Mars Exploration Program of the NASA Office of Space Science (now the Science Mission Directorate), with very strong support of the then NASA Office of Aeronautics, in response to the Office of Space Science Announcement of Opportunity (AO) for Mars Scout Missions. ARES was selected as one of four finalists in the 2002

Mars Scout mission opportunity (Eventually, the University of Arizona's Phoenix stationary Mars lander mission was selected to be the first Mars Scout mission with a 2007 launch scheduled). The ARES Mars airplane and Mars mission is a continuing research and development activity at NASA Langley and the ARES proposal will be resubmitted to the Mars Exploration Program for the next Mars Scout mission opportunity in 2006 for a flight on Mars in 2011.

Even though a Mars Airplane mission hasn't flown yet, MarsFlight should create an experience very similar to how the ARES/Mars Airplane team feels an actual Mars Airplane mission will be conducted.

While the Actual ARES scout mission will be Autonomous, we have decided to add a component of flight testing in Virtual Reality to enable users to interactively fly a mission in real-time so they don't get bored or lose interest. The ability to fly a fully autonomous mission is still available.

The design outlined here represents a good balance between education, real-time interactivity, and a realistic Mars Airplane mission scenario.

1.2 Originality

To our knowledge, no similar simulation scenario has ever been developed. This simulation differs from any other by placing students in front of a control console on Earth so they may fly the craft remotely. In addition, this simulation is being specifically designed to educate and inspire students while they are immersed within a game-like interactive visual environment.

1.3 Goal

MarsFlight will support two primary goals – Education and Inspiration.

Education – MarsFlight will be used to educate our next generation of explorers. A comprehensive set of middle school and high school educational curriculum will be developed that is based upon a student's use of the MarsFlight Simulation. Many learning opportunities involving the student's use of Science, Math, and other subject areas will be built into the MarsFlight software and are described in this document. Learning opportunities include data acquisition and graphing, learning about the Mars Airplane's research investigations, and learning how the environment of Mars differs from the environment of Earth and how this affects the way airplanes fly in both regions. Students will also learn a great deal about how the Earth's magnetic field differs from the magnetic field on Mars and why a compass won't work on Mars. All users will be exposed to some of the stress and anxiety that real planetary scientists have to endure when designing such ambitious missions that open up our frontiers of space.

Inspiration – MarsFlight will be used to inspire our next generation of Explorers. Every student who flies MarsFlight will be placed in the role of the Mars Mission scientist actually controlling the craft and determining the outcome of the mission based upon where they chose to fly and how they execute their mission. Real-time interactivity, highly authentic displays and the thought of controlling an airplane that will someday fly above the surface of another planet will help to provide inspiration and wonder for students.

It is highly anticipated that MarsFlight will make learning fun, thus making it a widely used simulation at both homes, schools, museums, and other venue's.

1.4 Genre

MarsFlight IS NOT a game. It is an Educational Simulation designed specifically to inspire and educate our next generation of Explorers as only NASA can. MarsFlight immerses students in the excitement and challenge experienced by a Planetary Mission Scientist designing, testing, and flying an Airplane on the surface of Mars.

2.0 System Requirements

While the Windows/Personal computer dominates the desktop when considering the entire world's population, the Apple Macintosh platform is used by many schools (The target audience we wish to reach) across the country. Therefore, MarsFlight must be able to run in the Windows (PC) environment and the Apple Macintosh environment.

2.1 PC Requirements

Minimum Specs. For Windows/PC

1. Pentium 4 Processor (2.4 GHZ) or better, 512 MB RAM
2. Microsoft Windows (Windows 2000 or above)
3. SoundBlaster compatible sound card
4. OpenGL graphics board with Minimum 128 MB (or more) dedicated video memory.

2.2 Mac Requirements

Minimum Specs. For Macintosh PowerMac

1. Power Mac G5 (1.8 GHZ) or better, 512 MB RAM
2. Macintosh OS-X or above
3. SoundBlaster compatible sound card
4. OpenGL graphics board with Minimum 128 MB (or more) dedicated video memory.

3.0 Development Requirements and Standards

MarsFlight is intended to be distributed to the public via the Internet and CD-ROM. Therefore, we require the ability to distribute the software to an unlimited number of users without purchasing run-time licenses or incurring any additional fees of any kind. This requirement MUST be kept in mind when determining the best software toolkit to use in developing the MarsFlight. In addition, MarsFlight must be developed for a dual (Windows/MAC) platform.

The preferred toolkit to develop MarsFlight is OpenGL and C++. This will ensure platform independence, the widest compatibility, and will hopefully avoid any license requirements.

A different toolkit other than OpenGL may be used provided our requirements for a dual (PC/MAC) version can be met as well as the ability to distribute this software to unlimited users without requiring run-time licenses or any additional costs of any kind beyond the initial development.

3.1 NASA Quality Standards

The National Aeronautics and Space Administration is synonymous with high quality standards of excellence. It is very crucial that MarsFlight adheres to the same high quality standards due to our planned eventual wide dissemination of MarsFlight to the public. Tens of thousands of people will use MarsFlight every year at many national or international exhibits that NASA participates in. In addition, it is expected that MarsFlight will be available to the public as a free download and will be distributed to educators and schools packaged on a CD-ROM. There are three areas of the software design that we are most concerned with.

1) Professional visual appearance of all on-screen displays
2) Realism/authenticity
3) Proper functionality and wide hardware compatibility

It should be emphasized that every effort most be made to assure that MarsFlight is widely compatible across varied computer systems with varied hardware. We are aware that it is unreasonable to expect MarsFlight to run on 100% of the systems that it is installed on even if the minimum system requirements are met. However, we expect MarsFlight to install and run successfully on 90-95% of the systems that meet the minimum system requirements.

It is extremely important that the developer work closely with the NASA team throughout the development process to assure realism and authenticity of the scenario presented here. This is particularly important when implementing code for the flight/dynamics models and other physics/dynamics processes.

Note: NASA will provide most 3-D models and animations for MarsFlight. Particularly, they will provide the 3-D digital terrain for Mars, the 3-D model of the Mars Airplane, and all animations.

3.2 MarsFlight Real-Time Performance

Nearly all portions of the MarsFlight software require complex visual data to be presented to the user at a high frame rate. The visual database is made up of the entire surface of Mars, as well as real-time displays, and vehicles. The visual database may contain other elements as well. In consideration of the fact that we want a rich visual experience presented to the user, we require that an average frame rate of 25 frames/second be maintained at all times. In addition, terrain, vehicles, and display panels must be as visually stunning as is possible while still maintaining this average frame rate. In consideration of these overall requirements, it is understood that paging in and out of Mars Terrain (Textures) as well as level-of-detail switching may be required in order to obtain the best possible visual experience.

3.3 NASA Rights to Data

NASA shall retain full rights to copy and distribute this application in any way it feels fit to an unlimited number of users such as educational institutions, students, and the general public.

3.4 NASA Evaluation and Test Criteria

3.4.1 During Development

NASA will require a progress report from the developer once every two weeks during the development phase. This progress report must include the general tasks worked on the previous 2 weeks, any problems encountered, and any questions. In addition, NASA encourages the developer to send beta versions of the software when appropriate since it is difficult to know how a particular screen will look and how a function will operate until it is actually implemented. It is also easier to make adjustments and corrections earlier in the development timeline rather than later.

3.4.2 After Software Delivery

Once the final deliverable is sent, NASA will require a minimum of 2 weeks to thoroughly test and evaluate the software. This testing will involve the project manager for MarsFlight development, as well as the scientists and engineers working on the actual ARES Mars Airplane Project. In addition, NASA will require a 2-month beta testing period following their evaluation. The beta testing will involve the simulation’s primary audience – middle and high school students.

4. Deliverable Schedule (Timeline)

Phase 1
The deliverable from Phase 1 will enable MarsFlight to be utilized in a NASA Agency-wide Exhibit. This phase will enable guests who visit NASA's exhibit to experience a flight of the Mars Airplane, ARES as they test it in a virtual environment prior to the actual flight. This task includes the development of realistic flight dynamics, the ability to control the flight path and the ability to control and view the video from a remote video camera mounted on the aircraft (or traveling with it). Phase 1 only requires MarsFlight to be developed for the PC/Windows XP/2000+ environment.

Phase 2
Phase 2 will continue to develop the simulation where phase 1 left off and will add an autonomous flight mode to the simulation where users can define a flight path that the aircraft will follow when released near the surface of Mars. Phase 2 will also add a demo mode as well as additional graphic displays, and the ability to acquire and print magnetic field mapping data from a data file during a flight.

Our entire development timeline is shown in Figure 1.

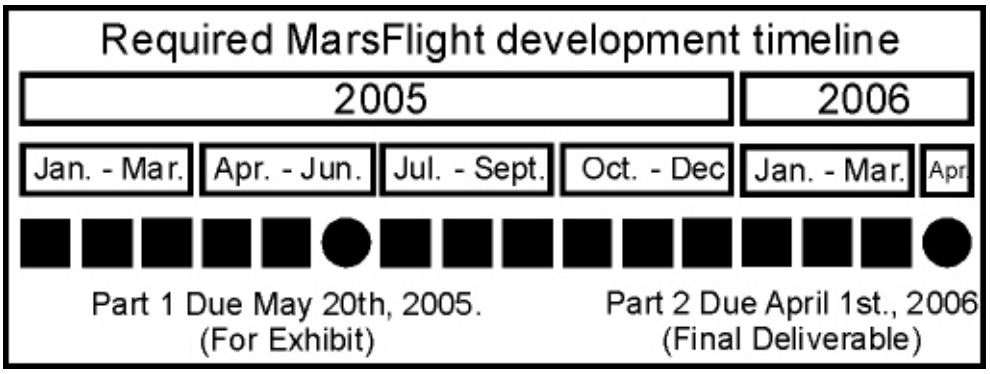

Figure 1 – MarsFlight Timeline

5.0 Design Details

5.1 Overview

MarsFlight will enable users to fly a Mars Airplane near the surface of Mars to collect data on the Magnetic field that they can print out and analyze following the completion of their mission. Users will be able to select one of two modes of operation – a flight test mode where they can interactively fly the craft in Virtual Reality at an Earth-bound NASA computer laboratory using a flight stick, and an autonomous mode where they can select waypoints and altitude to direct the craft where to fly autonomously. A component built into the MarsFlight software will enable users to control the radio transmitter used to relay Mars research data

back to Earth. Using this scenario, MarsFlight provides additional interaction and feedback for advanced users or two users working cooperatively. MarsFlight has been designed to support two different display configurations – one using a single screen with three windows for home or classroom use, and another using three separate displays (One window on each display) to support a NASA exhibit or other museum exhibit. MarsFlight will provide ultra-realistic scenery of the surface of Mars, graphical special effects, sound, an authentic Mars Airplane flight model, graphic feedback and display panels, and educational curriculum to deliver a unique and inspiring visual experience.

5.2 Main User Interface

This section will describe our concepts for the main MarsFlight user-interface and visual environment. We are not entirely sure how best to implement our concepts into the software so we will leave this up to the developer provided our requirements can still be met.

1 – MarsFlight must be able to function within two entirely different display environments. They are …

- On a Windows/Mac Personal Computer system with a single display for use in classrooms and in homes.

- On a Windows/Mac Personal Computer System with THREE separate displays for use at NASA Public Exhibitions and in museums and better-equipped classrooms/educational institutions.

2 - For both display environments above, MarsFlight must support any graphics resolution in order to accommodate a display on regular CRT and LCD (4:3 aspect) displays, Wide Screen Plasma displays and projectors 16:9 aspect), and the challenging VisionStation hemispherical Dome display as well as other current and future displays.

3 - The display environment must be easy to maintain, and configure and should follow a regular Windows convention as most people are already familiar with.

4 – When a new display environment is configured (changed) by the user, it should be saved so that it is reloaded the next time the simulation is run.

5- The MarsFlight user interface will consist of three windows – each would be resizable, and repositionable on either a single (or a combination of three) monitor(s). One window (Referred to as the top window) would be a wide screen view and would be the main display window where most of the action takes place (Such as mission design, flight testing, flight execution, Help and mission animations, and final statistics). This view would normally be shown on the large plasma display (When MarsFlight is used at an Exhibition) or on the wide, top

window of a single display. Since this will be the largest display, guests would normally be focused on this display. The two other windows – Lower left and Lower Right would be used to display very interesting data that changes in real-time to reinforce the realism and authenticity of the large (top) display. However, these two bottom displays should not display critical information that requires a guest to view them in order to complete their mission successfully. While it isn't as much a problem when all three windows are displayed on a single display (As in the left illustration below), it may be a source of confusion to guests if we change their focus from one monitor to another that requires a substantial degree of eye movement. See figure 2.

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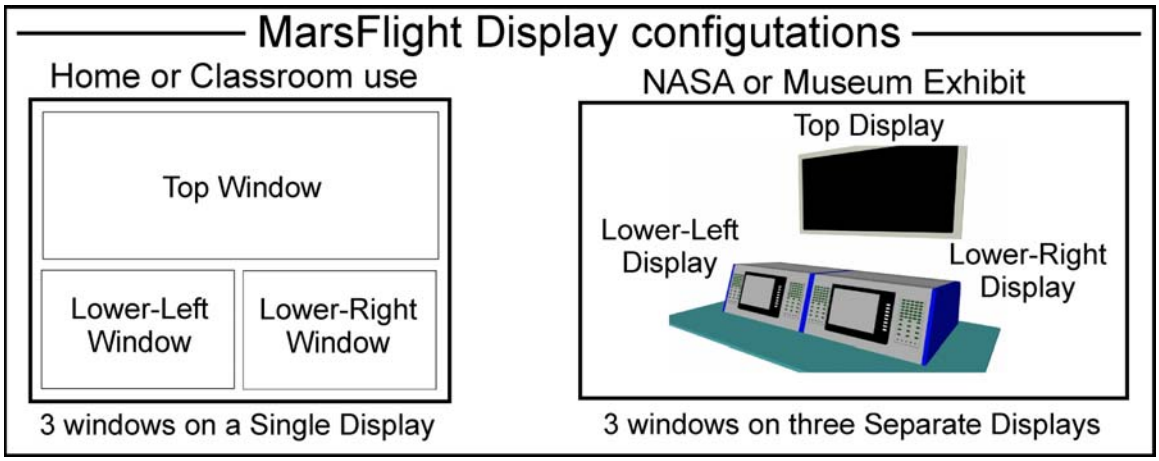


Figure 2 – MarsFlight display configuration

The lower left and lower right displays would be used for real-time spacecraft status, and data from research instruments onboard the Mars Airplane that would be useful and exciting for spectators to view as well as the actual guest flying the simulation.

5.3 MarsFlight Virtual Environment

(NASA will provide the Digital Terrain, the Mars Airplane model and all animations.

The MarsFlight virtual environment consists of the Mars Airplane, as well as the entire planet of Mars (Digital Elevation Model and terrain map) and any special features that are on the planet's surface (Previous Mars landing craft, for instance). Actual digital elevation data from the Mars Orbiter Laser Altimeter (MOLA) must be used to create the surface terrain unless more accurate "authentic" data exists at the time that the terrain is created. In order to create a very accurate representation of the surface texture of the entire planet Mars, the most detailed photographs of the surface must be used. Once a Mars globe is rendered in its highest detail using actual Digital Elevation data and actual photographs, this mesh should be optimized and loaded in order to provide the

required frame rate requirements. To help meet the minimum frame rate requirements, the paging in and out of textures should be used so that only the textures actually seen on the screen should have to be rendered at any time. Ultimately, in its final form, the surface texture at any point on the surface should look realistic if viewed at 30 feet distance which is the estimated distance from the camera mounted on the Mars Airplane to the surface when the plane has landed (crashed). A X,Y coordinate system (Latitude/Longitude) should be established for the 2-D terrain map of Mars to not only provide a readout that can be displayed during program run, but also to help identify the precise location of objects placed on the surface.

The MarsFlight Virtual environment may also consist of the planet Earth as well as up to three communications satellites Orbiting Mars to use for the “Satellite Communications Network” display included on the Lower Right Auxiliary display. The planet Earth and the three Mars-orbiting satellites probably don’t have to be rendered with the extreme realism that all other elements do since they are only shown on an illustration on one of the displays.

5.4 Dynamics/Math

This section describes the basic requirements for the math/dynamics that are required for MarsFlight. The developer will have access to Mars Airplane program scientists at NASA to consult with during dynamics/math development to assure authenticity. Consultation is required to assure a realistic scenario.

5.4.1 Mars Airplane dynamics Module

A dynamics/math module will have to be developed to aerodynamically represent an aircraft in flight within the Mars environment. Some of the flight parameters that will have to be taken into account include …

1) The weight of the aircraft (Weight gets smaller as fuel is burnt)
2) Engine power selected (By the throttle integrated into the joystick)
3) Rate of fuel burn
4) Quantity of fuel available (The quantity of fuel is fixed but a percentage of fuel available is variable and can be set in the setup screen)
5) Atmospheric Density.
6) The position and orientation of the aero-surfaces on the aircraft.

The Mars Airplane engines will “pulse” at a variable rate and duration to control the velocity of the aircraft.

In addition, an “easier” flight mode should be implemented to allow younger or less-experienced users to fly. However, when this “easier” mode is selected, an Icon or text should be clearly displayed on-screen ON THE MAIN (Top Wide

Screen) display indicating that the easier (non-realistic) flight mode is currently being used.

5.4.2 MarsFlight Planetary Dynamics

In order to simulate a realistic environment when users fly near the surface of Mars, we require the authentic and realistic simulation of the planet Mars rotating on the proper axis in orbit around the sun. A display of the sunlit and dark side of Mars will be required on several of the displays. The actual location of the sun and the location and rotation of the Planet Mars will be determined by the launch date set in the setup screen.

The MarsFlight planetary dynamics may also consist of the planet Earth as well as up to three communications satellites Orbiting Mars to use for the “Satellite Communications Network” display included on the Lower Right Auxiliary display.

5.4.3 Power, Propulsion, and Communications emulation

In order to drive one of the displays, and to involve users in some of the decisions actual mission scientists have to make, it will be necessary to simulate the basic operation of the Mars Airplane’s Power, propulsion, and communications systems within the MarsFlight Software.

The Communications system will simulate the radio-signal data flow between the Mars Airplane flying near the surface of Mars, three communications satellites orbiting Mars, and an Earth-based satellite receiving station. See diagram 1

Data is acquired from onboard instruments within the Mars Airplane at a data rate that is proportional to the velocity of the airplane. Quite simply – When the airplane goes faster, it acquires data at a faster rate. When the airplane acquires data, it has to be sent somewhere … either to one of the three Mars-Orbiting satellites or back to Earth directly. In order for the Earth or a Mars-Orbiting satellite to qualify as a receiving station, it must be in-view (I.e. Above the Mars horizon with respect to the Mars Airplane which is sending the data). If the data has no where to go (I.e. No Mars-Orbiting satellite or the Earth is above the horizon), the data will be stored in temporary memory onboard the Mars Airplane called a data buffer until the data can be sent (I.e. Earth or a Mars-Orbiting satellite becomes available). The memory buffer is a limited size and when the data buffer fills up beyond capacity, data is lost. The data buffer onboard the Mars Airplane can also fill up if the data being acquired from onboard instruments is at a faster rate then the data can be sent (Either to a Mars-Orbiting satellite or directly to Earth). The uplink data rate (The data rate of data being sent from the Mars Airplane to a satellite or to Earth) is dependent on the distance the signal has to travel, and on the power of the transmitter. The drain on the power system (batteries) is affected by the power of the transmitter and on the data rate. As

transmitter power is increased, and thus data rate, drain on the batteries also increases.

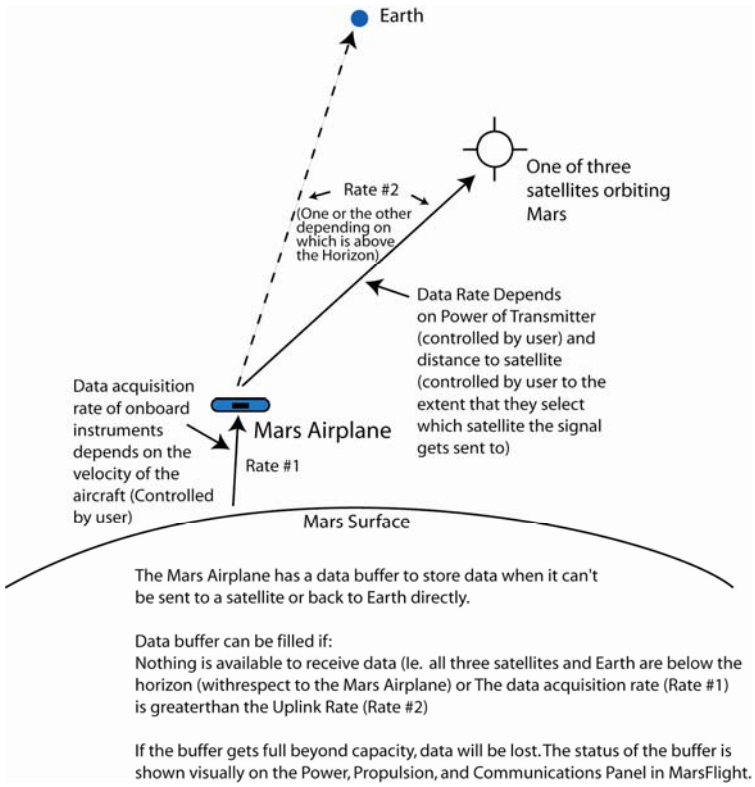


Diagram 1 – Data Communications System Pictorial

The Power, Propulsion, and communications system will be capable of operating in manual or automatic. If operated in manual, the student will select which satellite (Or the Earth) receives the data and what the power of the transmitter is. If operated in automatic, the computer makes these decisions to provide the best performance.

The propulsion system mimic's the action of the Mars Airplane (ARES) engines. Movement of the throttle causes the engines to change their pulse rate and duration causing the aircraft to move slower or faster. However, if the airplane goes faster, the rate at which data is acquired onboard the aircraft (Incoming Data Rate) increases which could cause the memory buffer to fill up faster. If this happens, a user may have to make a decision to slow down or to switch to a satellite that offers a longer distance for the radio signal to travel to Earth – both events would slow the data rate of the data being sent to Earth thus giving the buffer time to empty. The mission is over when the fuel is depleted.

The Power system mimic's the operation of the batteries and the load placed on them (I.e. The scientific instruments, avionics, and switched devices). As mentioned earlier, a higher power drain on the batteries occurs if the transmitter

data rate is higher or the transmitter power is higher. When the batteries are depleted, the mission is over. The following chart below summarizes the basic operation of the Power, Propulsion, and Communications Systems.

Simplified Functionality Rules
For the Power, Propulsion, and Communications systems

Communications

- Software will mimic the basic functioning of the Communications System.
- In order for a data to be sent from the Mars Airplane to one of three Mars-Orbiting satellites, or to Earth, at least one of them has to be ABOVE the Horizon In View (With respect to the location of the Mars Airplane.)
- The uplink data rate of the data sent from the Mars Airplane to one of three Mars-Orbiting satellites or to Earth is dependent on the distance the data has to travel, and on the power level of the transmitter. Higher distance = lower data rate.
- The data rate of experimental data acquisition from instruments onboard the Mars Airplane is dependent on the velocity of it. The faster the plane goes the more data that can be collected per second.
- There is a temporary memory storage area on the Mars Airplane called a memory buffer. This is a specific size. Data is stored in the memory buffer IF there are no satellites (Or the Earth) to send the data to or if the data rate of experimental data acquisition is greater than the uplink data rate (From the airplane to a Mars Orbiting satellite or to Earth).
- If the memory buffer fills up beyond capacity, data will be lost.

Propulsion

- Software will mimic the basic functioning of the Propulsion System.
- Mars Airplane has a specific quantity of fuel onboard but the percentage of fuel actually used for a mission can be set in the setup screen.
- Fuel usage is dependent on the velocity of the airplane. Faster velocity = Higher power = more fuel usage/sec. Slower velocity = Lower engine Power = less fuel usage/sec.
- Mission is over when fuel is depleted.

Power

- Software will mimic the basic functioning of the Power System.
- Power drain on batteries is dependent on the data rate of the transmitter. Higher data rate = Higher power drain. Lower data rate = Lower power drain.
- Mission is over when the primary and redundant batteries are depleted.

5.5 MarsFlight Detailed Program Flow

The block diagram shown in figure 3 shows the basic MarsFlight program flow.

5.5.1 – Data Loading Screen

Due to the rich and authentic virtual environment that MarsFlight will require, we expect that the data will take a considerable time to load following initial program execution. This screen will include a very cool graphic with the name of the program, the name of the developers (If desired) and the version of the software. To assure users that data is being loaded properly, a “data-loading/progress” display will be included as shown in figure 4.

Figure 4 – Animated Data Loading ICON on “Data-Loading” screen.

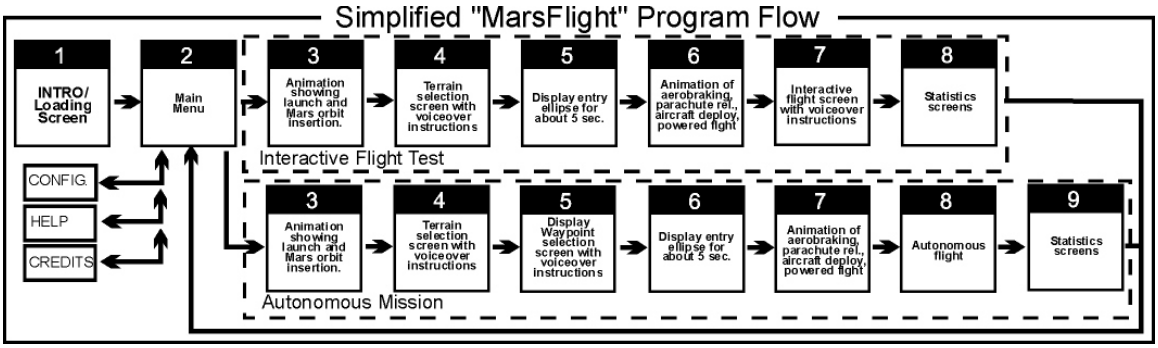


Figure 3 – MarsFlight Program Flow (Block Diagram)

This display will initially start out as all RED segments (No data loaded). Then as data is loaded, the segments will turn GREEN starting with the middle/top segment and moving clockwise until all segments are green (Data fully loaded).

Finally, the data loading screen should indicate at the bottom what type of data is being loaded … Terrain, sounds, etc … The “Data-Loading” screen is shown in Figure 5.

5.5.2 The Intro Screen/Main Menu

This screen will also display a cool graphic as in the data loading screen but it will provide a menu to enable the guest to start the simulation, to configure it, and to get help.

The following menu choices should be implemented …

1 – Interactive Flight Test – clicking the Mouse on this ICON will initiate a Mars Airplane flight test where a user can interactively fly the craft in Virtual Reality using a joystick.

2 – Autonomous Mission – clicking the mouse on this icon enables you to simulate a mission similar to an actual Mars Airplane flight whereby the user selects waypoints and the plane automatically follows them.
2 – Mission Configuration – Clicking the Mouse on this ICON will enter the MarsFlight configuration screen.
3 – Help (MarsFlight Command Reference)
4 – Credits – Here is where the credits will go for anyone who wishes to give themselves credit as well as crediting any organizations that provide data or resources to this project.
5 – Exit to Windows – Clicking this icon will exit MarsFlight and return to Windows. Exiting to Windows will create or append the usage data file with one entry representing the number of times MarsFlight was flown since the last “exit”.

Figure 5 – MarsFlight “Data-Loading” screen

The Intro/Start menu will be the only location where a guest may initiate the “Interactive flight test”, the “Autonomous mission” or may enter the Mission Configuration. An example of this screen is shown in Figure 6.

5.5.3 Launch from Earth/Mars orbit insertion animation. (This Animation will be provided by NASA)

MarsFlight attempts to provide users with the “Full picture” of how the aircraft gets to Mars and conducts its scientific mission. Therefore, when users select either “Interactive Flight Test”, or “Autonomous mission”, they will first see a short animation clip showing the launch from Earth, cruise to Mars, and then Mars Orbit Insertion as the following stills below depict.

Figure 6 – MarsFlight Main Menu

The animation should not last more than 15-20 seconds and should be narrated and background music should be added. In addition, since this animation represents an extremely long time duration (perhaps as long as a year) and the animation represents many breaks in time, it is extremely important (And educational too) to add an elapsed time display to this animation in the lower/center of the screen in the format …

Month, Day, Hr:Min:Sec (in 24-hr format) followed by the name of the event

For Instance – Month 00, Day 15, 11:00:03 – First Stage Deploy
or Month 09, Day 05, 21:00:34 – Aero Shell Shroud release

Note1 – while these events will be verbally described in the animation, they should also be printed on-screen (For the hearing impaired).

Note 2 – Keep in mind that the animation will be shown on the main (Top) Window (Display).

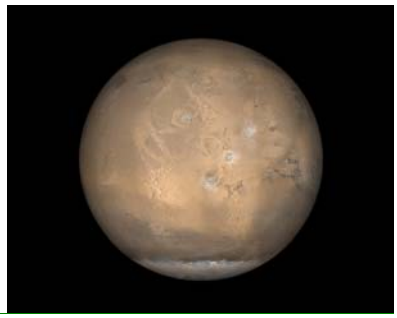
Note 3 – The animation developer needs to keep in mind that the Elapsed Time/Event Description display should be clearly visible throughout the animation irrespective if the background is light or dark. We prefer to deal with this issue by placing a 50% transparent box around the lettering which is a contrasting color. See how we have handled this many of the MarsFlight display panels in section 5.5.8.1.2 and section 5.5.8.2.2.

5.8.4 Airplane entry location over Mars

Following the previous animation, the user will select the location over Mars that they will deploy the Mars Airplane.

Users will use their mouse/trackball to rotate the Mars globe in order to position the terrain they want to fly over within the circle. Users will left-click on the arrow buttons on the right of the globe to rotate it in any direction. Left-clicking on an arrow key causes motion as long as the left button is pressed. A display the coordinates in the center of the circle are continuously displayed as the globe is rotated. When the user gets to the location they want to explore, they left-click on "Continue" to go on to the next step. This display is shown in Figure 7. If "Autonomous Mission" was selected from the main menu, go to the next step (Setting Waypoints for the autonomous mission), otherwise skip next step and go to the Entry Ellipse display.

ANIMATION SHOWN --- LIFT-OFF FROM EARTH, CRUISE TO MARS (15-20 SEC.



→ Note: for the picture shown above, Mars should be shown in the background (as shown) with a spacecraft heading towards it in the Foreground (Not shown)

5.5.5 Setting Waypoints for the "Autonomous mission"

Following the selection of an entry location over Mars, if a user selects "autonomous mission", the area they selected in Figure 7 will change from 3D to 2D and will morph or zoom into the Waypoint Selection screen which is shown in Figure 8. Users will have the ability to select a minimum of two and a maximum of five waypoints that the airplane will follow during the flight. While the flight control will be non-interactive, students do have to select the waypoints on a map as well as the altitude at which the plane will fly.

The waypoint selection display Is shown in Figure 8. As the user moves their cursor over the map, the coordinates of the point (at the cursor) will be displayed at right in the Latitude/Longitude display. Users will select each waypoint, one at a time by moving the mouse/trackball cursor over the map and clicking the left mouse button. After they select each waypoint, a pop-up box will be displayed that enables them to select altitude for that waypoint. To aid them in selecting a flight path that supports good aerodynamics and good atmospheric density, a

scale will be displayed in the pop-up box that shows the density at that point over the terrain at various altitudes. Users would want to move the slider towards the green regions and away from the red regions to help avoid problems. Each click of the mouse will create one waypoint at the point they click and each one will be numbered (as shown below) from one to five. In addition, the set point altitude will also be displayed by each point. The user will not be permitted to enter more than five waypoints – if they try, they will not be displayed/used.

After setting Waypoints, there should be some checks to assure that the flight can be successful.

Figure 7 – Orbit Entry selection for "Interactive Flight Test"

There is a button available to clear all waypoints and re-enter should the user make a mistake. If the user clicks this button, all waypoints will be erased and they can enter up to five more. Users will not be permitted to continue unless at least two waypoints are set. When 2 to 5 waypoints are set, the user will click "Continue" to go on.

5.5.6 Entry Ellipse Display

Following the selection of an entry point (Interactive flight) or waypoints (Autonomous mission), a display showing the entry ellipse will be shown for about 5 seconds. This ellipse indicates the uncertainty of where the Mars Airplane will enter based upon many factors such as the performance of the parachutes, the actual density of the atmosphere where the plane enters, etc. The landing ellipse could morph from the previous entry point selected over the terrain. An entry ellipse is shown in figure 9.

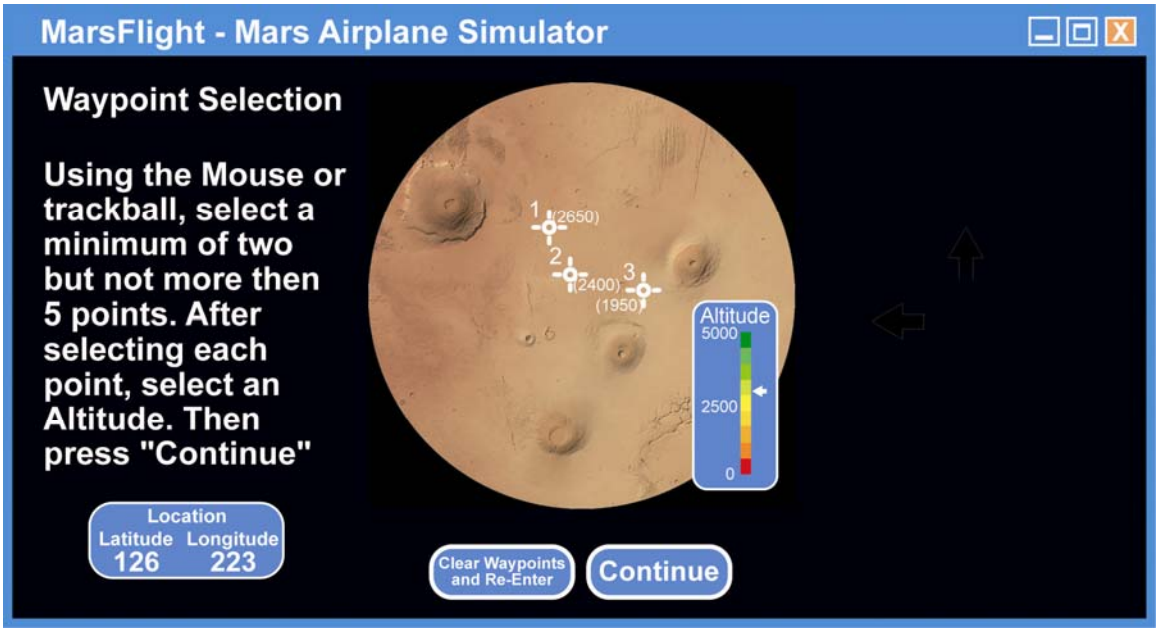


Figure 8 – Waypoint Selection screen for Autonomous mission

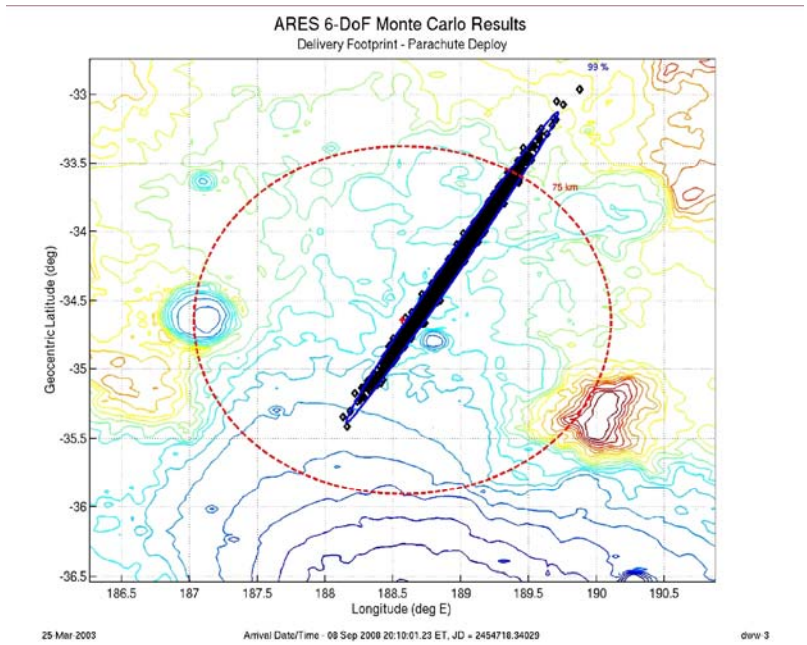


Figure 9 - Entry Ellipse

5.5.7 Mars Airplane Release, unfurling, and powered flight Animation

In order to educate a guest about an actual Mars Airplane flight over the surface of Mars, an animation will be shown illustrating the steps the airplane took from release up until the student-controlled flight. The animation should not last more than 30-45 seconds and should be narrated and background music should be

added. In addition, since this animation represents an extremely long time duration (perhaps as long as a year) and the animation represents many breaks in time, it is extremely important (And educational too) to add an elapsed time display to this animation in the lower/center of the screen in the format …

Month, Day, Hr:Min:Sec (in 24-hr format) followed by the name of the event

For Instance – Month 00, Day 15, 11:00:03 – First Stage Deploy
or Month 09, Day 05, 21:00:34 – Aero Shell Shroud release

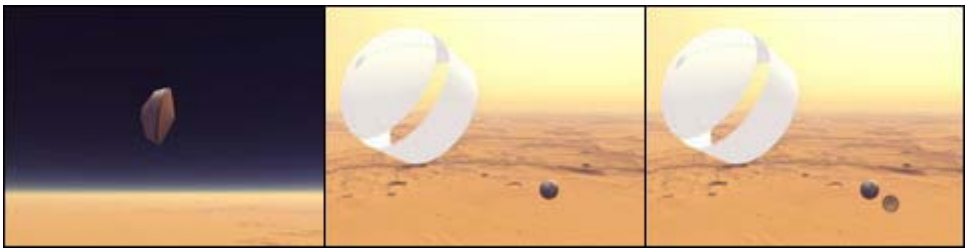
Note1 – while these events will be verbally described in the animation, they should also be printed on-screen (For the hearing impaired).

Note 2 – Keep in mind that the animation will be shown on the main (Top) Window (Display).

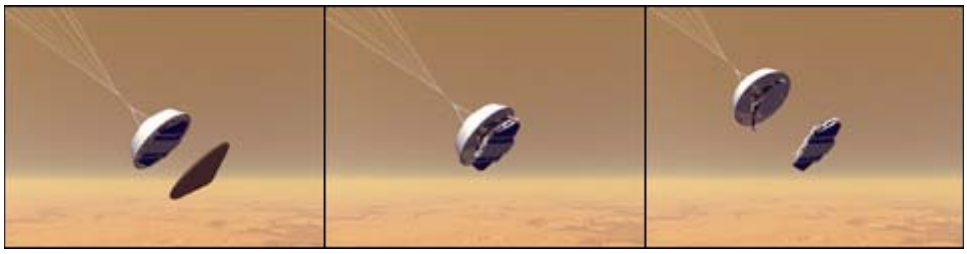
Note 3 – The animation developer needs to keep in mind that the Elapsed Time/Event Description display should be clearly visible throughout the animation irrespective if the background is light or dark. We prefer to deal with this issue by placing a 50% transparent box around the lettering which is a contrasting color. See how we have handled this in section 5.8.3 for the X-Position and Y-Position.

The following steps below depict stills from the animation. These steps should be included in the indicated order …

STEPS 4, 5, 6 – AERO BRAKING, PARACHUTE DEPLOY AND SHROUD DEPLOY



STEPS 7, 8, 9 – SHROUD DEPLOY 2, AIRCRAFT RELEASE 1, AIRCRAFT RELEASE 2



STEPS 10, 11,12 – AIRCRAFT UNFURLING 1, 2, AND 3

STEPS 13, 14, 15 – UNFURLING COMPLETE AND BRIEF AIRCRAFT POWERED FLIGHT 1, AND 2

Following the completion of the animation, the screen will morph into the Interactive flight test above the surface of Mars or the Autonomous mission (depending on what was selected from the main menu).

5.5.8 Mars Airplane missions

The Mars Airplane will be capable of flying two different types of missions – A fully interactive flight test in a NASA computer laboratory, and a fully autonomous mission near the surface of Mars. While the fully autonomous mission is the most realistic scenario for an actual Mars Airplane Mission, we are also providing the capability to simulate a flight test in Virtual Reality to enable users to take a more active role in interacting with this interactive simulation. The integrity and authenticity of the interactive simulation is still maintained since the setting for the Interactive flight is within a NASA Computer lab.

5.5.8.1 Mission type 1 - Interactive Flight Test

The Interactive flight test of the Mars Airplane provides users with the opportunity to fly a dynamic and interactive simulation which wouldn't ordinarily be possible with a real mission due to the communications delay between Earth and Mars. The setting for this scenario is an interactive computer laboratory at a NASA facility where users are able to immerse themselves within this simulation just as if they were on Mars. Every aspect of this interactive simulation is authentic and based upon the most reliable data relayed back from Mars-orbiting Spacecraft and landers.

5.5.8.1.1 Overview

The Interactive Mars Airplane Simulation enables users to fly the Mars Airplane in real-time over a highly authentic surface of Mars. Users will control their flight path with a joystick, and they will control the plane's velocity using a throttle control. In addition, users will have access to special functions by pressing various buttons on the joystick, or by clicking on various buttons using the mouse/trackball.

During an Interactive flight, users will view the video from a TV camera mounted on the Mars Airplane on their wide-screen display. This camera can either be attached to the Mars Airplane (Onboard view) or flying close by (Trail view). The "Onboard" or "Trail" view can be selected by pressing Joystick button #1. For either mode (Onboard or Trail), the user can select 3 or 4 auxiliary views for a wide range of viewing prospectives. During a flight, users will experience a wide variety of special effects including dust storms, and the exhaust from the engines (If they are looking that way). Audio effects can also be heard and include alert tones for various alert conditions such as low fuel, and air density too low.

During their flight, users will receive a great deal of status that can be viewed in a number of display windows placed at the bottom of the main window. Data such as Fuel remaining, speed, altitude, and atmospheric density can be viewed. Additional displays to supplement the main display are provided in the lower left and lower right displays and include a topography/flight envelope display, and a Power, Propulsion, and Communications System status display.

5.5.8.1.2 User Displays

The user displays seen during the Interactive mission include the Main display, and the Left and Right Auxiliary displays. Each of these displays are provided in repositionable, and resizable windows so that they can be configured to fit on a single display (In classrooms or homes), or on three separate displays (As in an exhibit). Please note that the developer may have to resize elements on these displays for a better and more consistent appearance.

Main Display

The main display is the display users will focus on most often as it provides the real-time view seen by the onboard (or trailing) TV camera. Several dynamic display windows are provided on the main display that provides users with the very latest status information on their flight. These are explained below …

Fuel – This display provides the percentage of fuel available in the fuel tanks onboard the Mars Airplane. The fuel tanks onboard the Mars Airplane will only hold a specific quantity of fuel. However, to provide additional mission scenarios, the percentage of fuel available for a particular flight can be set in the setup

screen from 1% to 100% of full tank. This display will always display the actual quantity of fuel in the tanks, so if the fuel qty. is set to 50%, then this display will read 50% at the start of a mission and go down from there. When the fuel level reaches 10%, the display will start to flash and an alert tone will be heard. The flashing gets faster as the fuel level approaches 0% and when fuel is all gone, the plane can no longer stay in the air.

Altitude – This display provides the actual altitude of the Mars Airplane above the terrain.

Atm. Density – This display provides a real-time display of the atmospheric density the plane is flying through at any time. The atmospheric density is an indicator of how well the aero surfaces will perform in keeping the plane in the air. This display provides both a bar graph and a numeric display. The bar graph is a visual indication of the plane's ability to fly through its environment. This bar graph should always indicate green for the best flight performance. If it is not green, the pilot will have to adjust the flight path or increase engine power in an attempt to increase performance of the airplane through the area they are flying.

Speed – This display provides a real-time indication of the speed of the Mars Airplane. This value will generally increase if engine power is increased.

Distance – This display provides a real-time indication of the distance traveled across the Martian terrain since the start of the simulation.

Figure 10 – Main Screen seen during "Interactive Flight Test"

Viewpoints

The user will have full control of a camera mounted on the Mars Airplane or traveling with it. Two views are possible – an “Onboard” view and a “Trail” view. These two views may be switched (toggled) by pressing button #1 on the Joystick.

“Onboard” view
In this view, the camera is mounted onboard the Mars Airplane at a fixed location but is able to rotate to provide a view looking forward, looking off the Right wing, looking backward, or looking off the left wing. These various views may be toggled using button #2 on the joystick. See figure 11.

“Trail” view
In this view, the camera is mounted at a variable location around the parameter of the Mars Airplane but an equal distance from it. The camera rotates so that the airplane is always in the foreground and the terrain and/or sky is in the background. The preset views available with “trail” mode include “from back looking forward”, “from front looking back”, and “from top looking down”. These various views may be toggled using button #2 on the joystick.

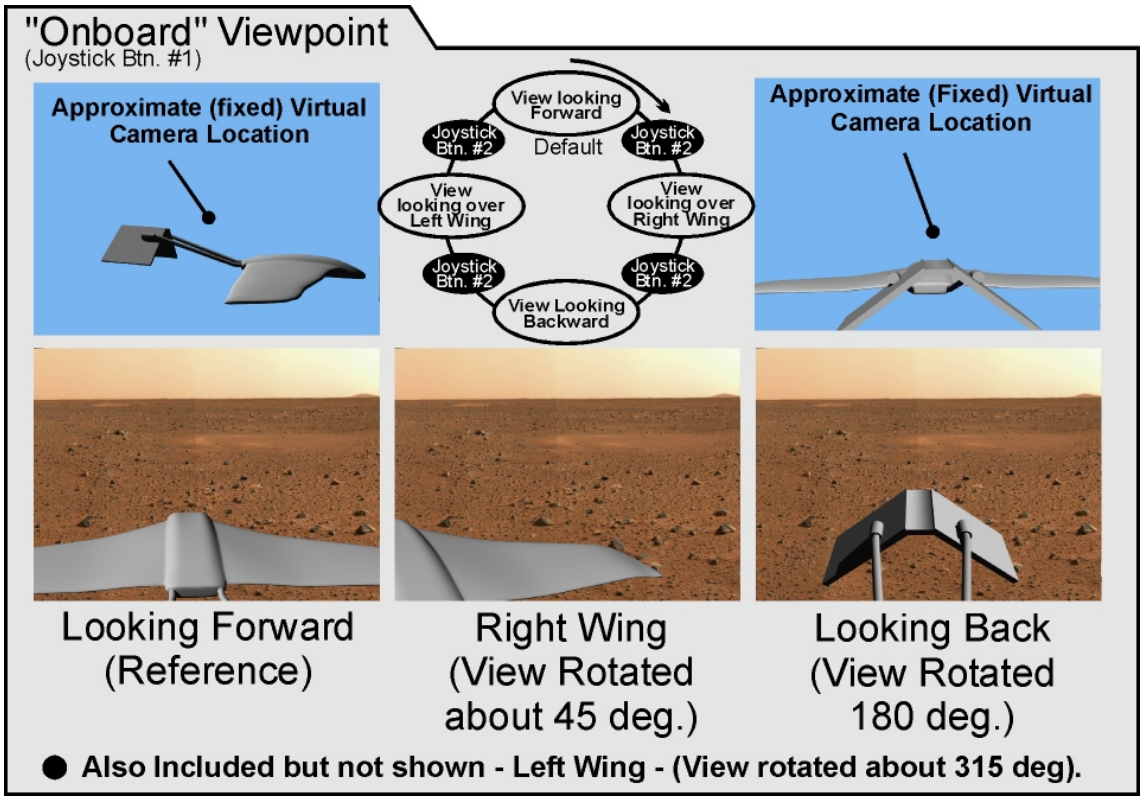


Figure 11 – “Onboard” Viewpoints

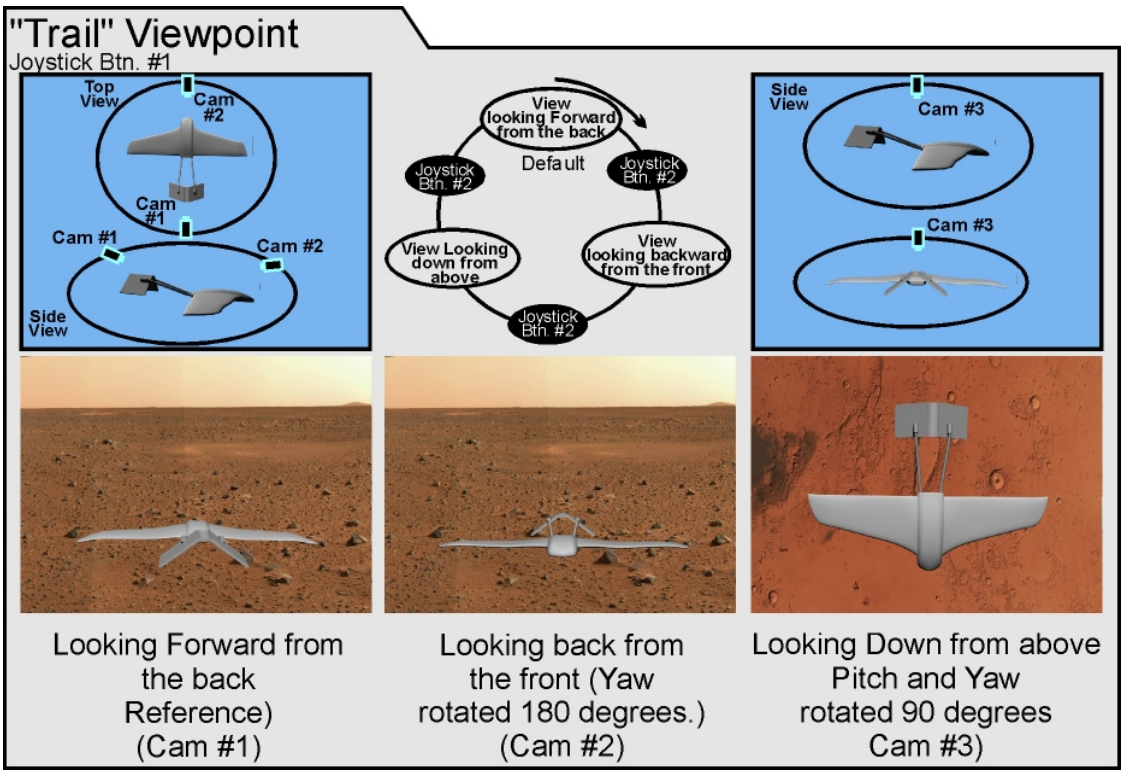


Figure 12 – "Trail" Viewpoints

One of the big advantages the trail mode offers is the ability for users to view the movement of the planes aero surfaces as they are being moved either interactively or autonomously. The user will also be able to view the functioning of the rocket engines if they are looking in that direction. See figure 12.

Lower Left display (Topography/Flight Envelope Display)

During the interactive flight, the left display will provide a visualization of the topography of the surface and the density of the atmosphere at the altitude the plane is flying at. See figure 13. The square surface area of the terrain shown in Figure 13 could be roughly the size of the area initially selected within the circle in figure 7.

The display indicates both topography and density. Topography can be viewed by observing shadows on a single-color (probably a shade of red) terrain as can be seen in figure 13.

Varying levels of atmospheric density can be shown using different colors as can be seen in Figure 13. A scale shown below the graph clearly indicates the meaning of the various colors on the display. The Density display shown on the chart represents a "slice" of the density at **the current altitude**. Several events such as changing altitude or flying faster can dynamically change the look of this graph.

An ICON of the plane will be shown in the center and the map will move appropriately in response to actual plane movements.

The three displays shown at the bottom of this display include “Atm. Density”, “Altitude”, and “Position (Latitude, Longitude)”. While atmospheric density can be calculated for the entire surface of Mars, this ability of the airplane to perform better within a lower-density environment can be improved by increasing engine velocity but at the expense of using fuel faster which ultimately leads to less data returned. There are algorithms and calculations to calculate the atmospheric density of Mars. If requested, the developer will be put in touch with a NASA expert to aid in the development of the atmospheric density calculations.

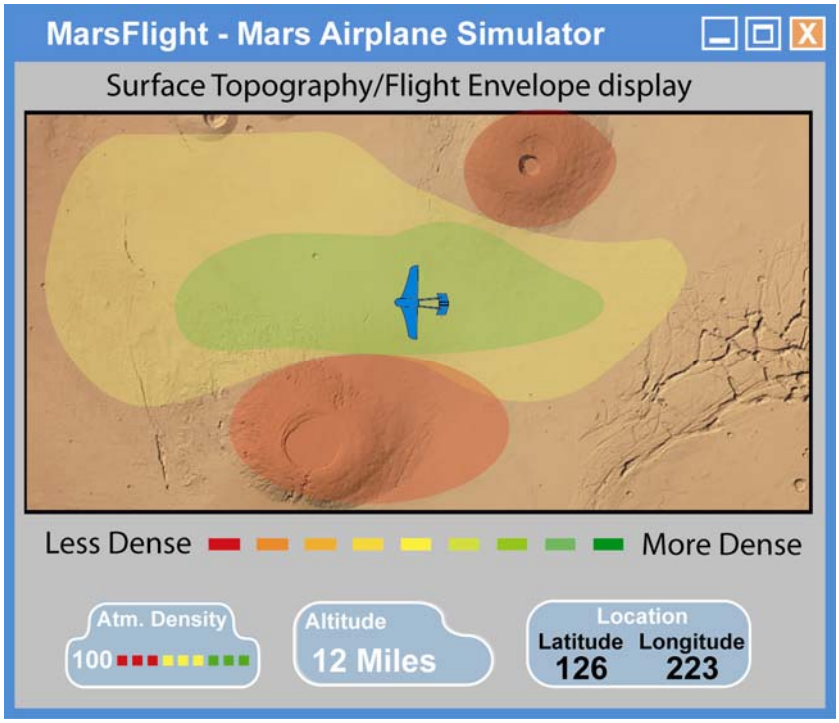


Figure 13 – Lower/Left Display – Surface Topography/Flight Envelope Disp. seen during “Interactive Flight Test”

During the interactive flight, the right display will be used to indicate the status of spacecraft systems such as power, propulsion, and the Communications satellite network. This display is designed to be Gee-Whiz and highly graphic while the data that drives these displays are explained in section 5.4.3. In addition, several buttons and a slider on this display enable users to provide real inputs to the communications system to select which Mars-orbiting satellite is being used to relay communications back to Earth, and to vary the power of the data transmitter. While the actual functioning of this display is provided earlier, this description includes the graphic and interactivity details.

Power – This display mimics the functioning of the batteries onboard the craft that power all of the systems and scientific instruments. Full power is indicated by ALL RED in the “Battery 1P” and “Battery 2P capsules”. As power is used up, Red disappears from left to right until the capsule is all WHITE. Red indicates FULL Power, White indicates NO power. The red dashes visually show the flow of power. Each other dash chases each other to indicate the flow of power from the batteries to the Avionics & Instruments and switched devices and back to the batteries. The “Battery 1R” and “Battery 2R” are redundant batteries are used once the primary batteries are depleted. Refer to the Functionality rules to learn how the batteries function on this display.

Propulsion – This simplified, highly graphic display indicates the status of the Mars Airplane’s propulsion system. The quantity of Oxidizer and fuel in the tanks is indicated by the ovals that are colored (The indicated color) when full. This data is derived from the Mars Airplane Flight/Dynamics model. When fuel is used up, the color disappears from top to bottom as more oxidizer and fuel are used up. A completely white tank indicates no fuel and the plane loses thrust and falls to the ground thus ending the mission. All three fuel quantities should be used up at the same rate. Every other dashed line chases each other indicating the flow of fuel (In the direction indicated by the green arrows) from the fuel tanks through the valves, and to the engine The dashed lines coming out from the engine that represents the engine plume also change and get longer as engine power is increased. Some method is used to indicate how fast the engine is “pulsed” and to show the relative power of the engines. The actual numeric Pulse Rate (Of the engines) and engine power are indicated as shown on the display. Refer to the functionality rules to learn how the propulsion system functions on this display.

Communications Satellite Network – This display simulates the basic operation of the satellite communications network used to radio data from the Mars Aircraft back to Earth. The location of the three satellites is placed in different orbit’s that are defined in the setup screen. The graphic display will visually show the location of the three satellites as they orbit Mars, the Mars Airplane, and the planet Earth. In addition, a (moving) dashed line will indicate the flow of information between the Mars Airplane and a satellite (or directly to Earth). Text will be used to label each satellite, planet, and the Mars Airplane as they move within their orbits and a color code could also be used. We are most interested in visualizing the satellites, Satellites Airplane Orbiting Mars, and communications between them. Due to limited Space in the display window, however, it is OK if the Earth goes off-screen in the display window provided a dashed line is included that still points to its off-screen location. Also, the location of the Mars Airplane MUST always be shown on this display even though one or several of the satellites may be behind Mars and not visible. In other words, the user’s viewpoint is attached to the Mars Airplane so it will always be in view, no matter what the orientation of the other planets and satellites are. There should NEVER be a situation where the Mars Airplane is not visible. If any signal is obstructed, the dashed line indicating signal flow will disappear until the signal is

no longer obstructed. Users will have the ability to interact with this screen in two ways – first, they will be able to select the satellite that the radio signal passes through on its way to Earth and second, they will be able to control the power of the onboard transmitter.

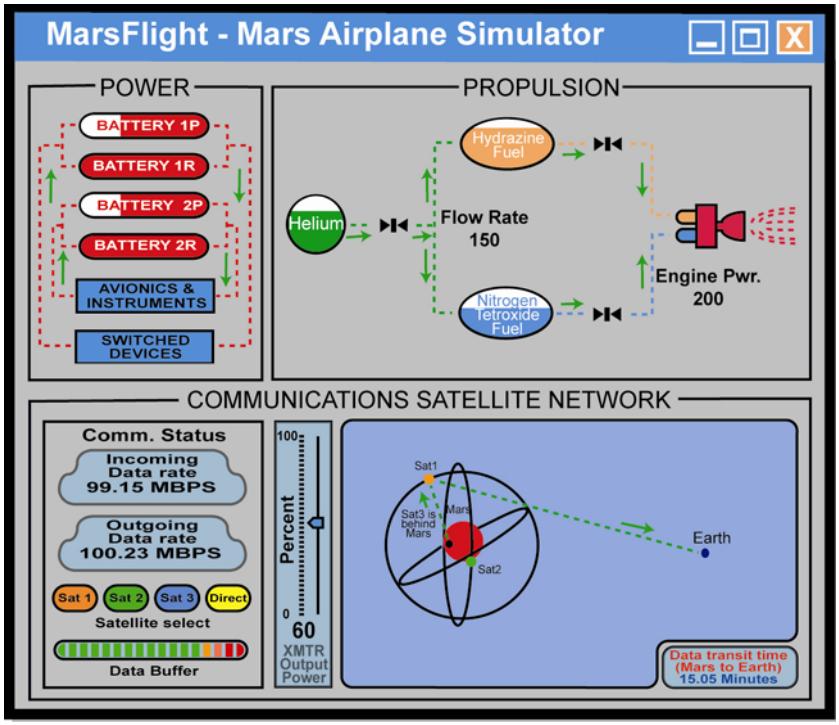


Figure 14 –Lower/Right Display – Power, Propulsion, and Communications seen during "Interactive Flight Test"

Refer to the functionality rules to learn how the propulsion system functions on this display.

5.5.8.1.3 Control Input

During the Interactive flight test mission, MarsFlight will accept user input from a variety of devices.

Joystick – The USB Joystick interfaces with the flight model to simulate the movement of the aero surfaces on the Mars Airplane to guide the craft through the thin Martian atmosphere. Forward/backward movements cause Pitch maneuvers, and Left/Right maneuvers cause roll maneuvers. A Yaw maneuver can be executed by pulling the trigger and then moving the joystick left/right. A Yaw can also be performed by executing a combination of pitch, and roll. Refer to Figure 15 to learn about the control surfaces on the Mars Airplane

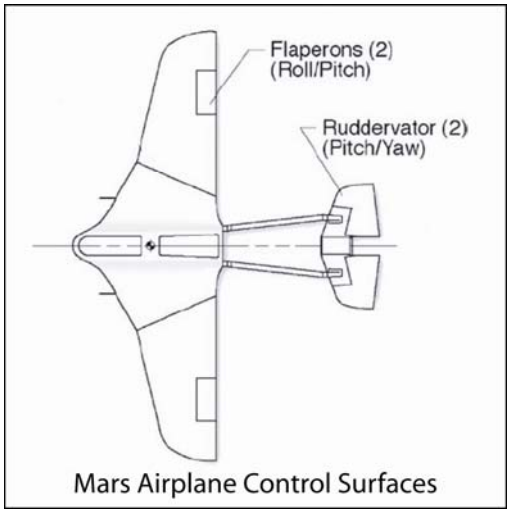


Figure 15 – Mars Airplane Control Surfaces

The throttle that is integrated into the joystick also interfaces with the flight model and varies the pulse rate and duration of the engines which in turns varies the thrust level.

A number of pushbuttons are also integrated into the Joystick. These pushbuttons control various features of the airplane. In order to maintain compatibility with lower-end and lower-cost joysticks, only lower numbered buttons should be used and no special buttons or controls (Such as the hat switch) should be used. Only a 2-Axis joystick is required for MarsFlight.

The currently defined pushbutton functions are as follows …

Pushbutton #1 - Toggle “Onboard”/”Trail” view
Pushbutton #2 - Toggle through the various viewpoints

It is important that a USB joystick be used for MarsFlight.

USB Mouse/Trackball - The USB Mouse or trackball are used interchangeably since either could be used just as effectively though we prefer a trackball for an exhibit. During the Interactive flight, the mouse/trackball will enable the user to select the Mars orbiting satellite that is used to relay the data signal back to Earth. During the interactive mode, the Mouse/Trackball will also enable the user to vary the power of the data transmitter.

Keyboard – The keyboard is only required for startup, and shutdown as well as maintenance functions. The keyboard is not required for successful operation of the simulation. However, the keyboard does reproduce all of the functions provided on the joystick.

5.5.8.2 Mission type 2 - Autonomous Flight at Mars

The Autonomous flight at Mars provides users with the opportunity to fly an autonomous mission using the most realistic scenario similar to the way an actual mission of the Mars Airplane may be conducted. Every aspect of this autonomous simulation is authentic and based upon the most reliable data relayed back from Mars-orbiting Spacecraft and landers.

5.5.8.2.1 Overview

The Autonomous mission will simulate an actual scenario for an Airplane flying on Mars. As a result of a long communications delay between Earth and Mars, a set of Waypoints were selected previously that will guide the airplane on its exploration mission without human intervention. Although the Joystick will not function in this mode to guide the craft, the joystick buttons will work to provide special functions such as the ability to select various viewpoints while “onboard” or “trail” mode is selected. The pulse rate and duration of the engines will be automatically set to maintain flight when following the waypoints that are set by the user. As with the Interactive flight, a wide-screen main view will be provided that shows the view from a TV camera mounted on the craft or traveling with it. A label placed on-screen during the Autonomous Mission tells users that their flight is automatic (I.e. Autonomous). The Lower Left display (Topographic/Flight envelope display) is also provided. During an autonomous mission, a trail shown on this display traces the flight path through the different waypoints. The Power, Propulsion, and Communications panel is provided in the lower/right display and it functions identically to the same display that is seen during the Interactive mission. See figure 14.

5.5.8.2.2 User Displays

“Autonomous” mode uses the same displays as the “Interactive mode with the following two exceptions …

1) During Autonomous flight, the words “Autonomous (Auto) Flight path” is displayed on the upper/center of the main wide-screen display. See figure 16.

2) During Autonomous flight, a visible line on the Topographic/Flight envelope display connects the waypoints together and visibly shows the ground track of an airplane icon as the Mars Airplane flies across the surface. See figure 17.

Figure 16 -– Main Screen seen during "Autonomous mission"

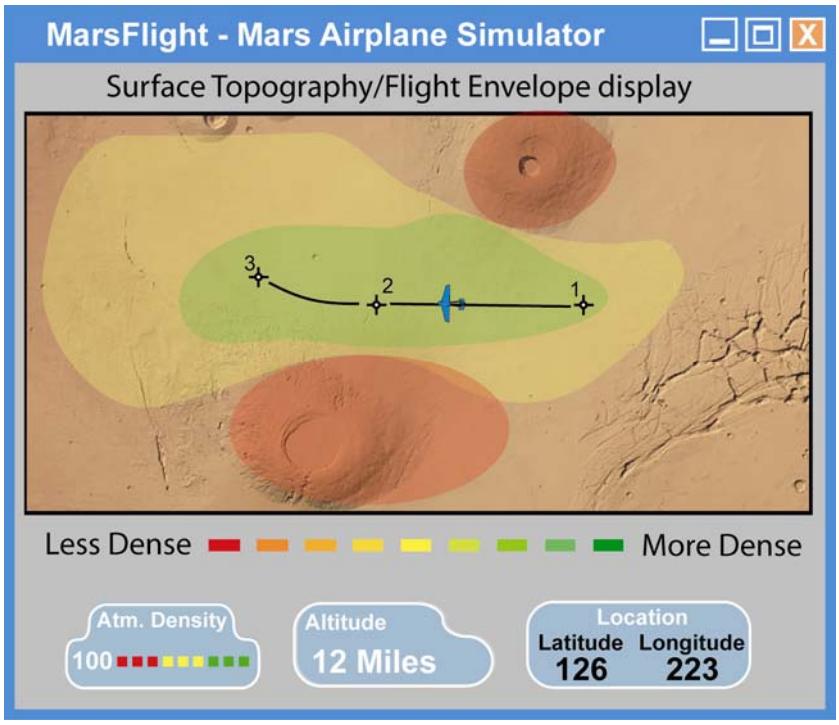


Figure 17 – Lower/Left Display – Surface Topography/Flight Envelope Disp. seen during "Autonomous Mission"

5.5.8.2.3 Control Inputs

Joystick – The joystick is not used to guide the craft since the flight path is autonomous in this mode.

While executing a waypoint flight, the airplane's aero surfaces should be programmed to move to attempt to stay on the correct heading, and to ascend and descend the plane to the set point altitude as the flight progresses.

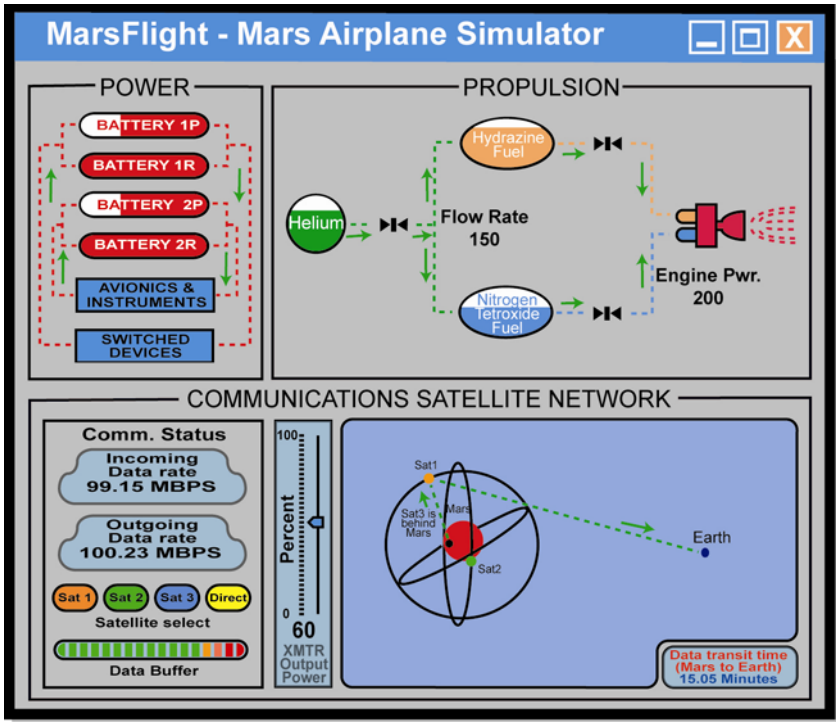


Figure 18 –Lower/Right Display – Power, Propulsion, and Communications status display seen during "Autonomous Mission"

Throttle – The Throttle is not used. Instead, the pulse rate and duration of the engines is automatically set to help assure stable flight throughout the autonomous mission.

A number of pushbuttons are also integrated into the Joystick. These pushbuttons control various features of the airplane. In order to maintain compatibility with lower-end and lower-cost joysticks, only lower numbered buttons should be used and no special buttons or controls (Such as the hat switch) should be used. Only a 2-Axis joystick is required for MarsFlight.

The currently defined pushbutton functions used during “Autonomous mode” are as follows …

Pushbutton #1 - Toggle “Onboard”/”Trail” view
Pushbutton #2 - Toggle through the various viewpoints

It is important that a USB joystick be used for MarsFlight.

USB Mouse/Trackball - The USB Mouse or trackball are used interchangeably since either could be used just as effectively though we prefer a trackball for an exhibit. During the Interactive flight, the mouse/trackball will enable the user to select the Mars orbiting satellite that is used to relay the data signal back to Earth. During the interactive mode, the Mouse/Trackball will also enable the user to vary the power of the data transmitter.

Keyboard – The keyboard is only required for startup, and shutdown as well as maintenance functions. The keyboard is not required for successful operation of the simulation. However, the keyboard does reproduce all of the functions provided on the joystick.

5.5.8.3 Events that can end a mission

Events that can end a mission include hitting the terrain (either landing or crashing), crashing into a mountain, running out of fuel, running out of time, Batteries depleted, or the atmosphere density too low to support flight. This event as well as perhaps others should be noted on the statistics summary screen at the end of each simulation run.

5.5.8.4 Special Graphic Effects

During the “Test flight in Virtual Reality” and the “Autonomous mission”, users will be able to visibly see the firing of the rocket engines on the Mars Airplane if they happen to be looking at them while “onboard” or “Trail” mode is selected. Some visualizations of what an engine firing will look like will be provided upon request. In addition, as explained previously, a special display will be implemented on one of the lower displays to show engine firing. The length of the exhaust will vary depending on the power selected (Adjusted using the throttle on the joystick). In addition, the engines will “Pulse” at a rate dependent on the overall weight of the vehicle (Which weighs less as the fuel is used up) and the acceleration (Such as required during a climb). The engine firing effect should be as realistic as possible. Drawings and illustrations of test engine firings will be provided to aid in making this simulation more realistic.

The effects of lighting on the surface of Mars should also be shown should be shown ON ALL displays including those in Figures 7, and 8. Depending on where

the user is looking and the location of the sun, shadows of the plane may be seen on the terrain on the main screen.

Simulate random dust storms. These regions of dust can be seen as you approach them and go through them, but they DO NOT affect the aerodynamics. These would be a special effect only.

5.5.8.4 Audio Effects

Audio effects will be used in many ways to enhance the simulation. Commentary and music will be added at the beginning of the Entry select and waypoint select screens as well as the interactive flight test screen to guide the user in the operation of these highly-interactive activities. The audio effects provide sound effects in response to actions that the user performs such as engine firing, and button pressing. Even if these sounds wouldn't be heard in real-life, they are still used to enhance the experience. Both the audio commentary and the audio effects can be turned on and off in the setup screen. Audio can also be heard during the animation sequences.

Audio heard in response to actions …

Engine firing

Audio heard in response to alerts …

Low Density, Low Fuel.
Stall

5.5.9 The statistics displays

The statistics displays provide the user with feedback on their flight. There are actually two displays comprising the statistics displays – the Statistics summary, and the Magnetic field mapping display. See figure 18.

5.5.9.1 Statistics Summary

The statistics summary is shown first and includes the following data …

1) The Mars orbit entry location – This indicates the longitude and latitude that the user entered Mars atmosphere.

Flight duration – This is the duration of the flight

Fuel used – This is the total fuel used during the flight.

Average Speed – this is the average speed of the aircraft throughout the entire mission.

Average descent rate – this is the average rate of descent throughout the entire mission.

Terrain Traversed – this is the total distance flown throughout the entire mission.

Final performance – This is the final result of the mission. Did the user crash, run out of fuel, run out of time, etc?

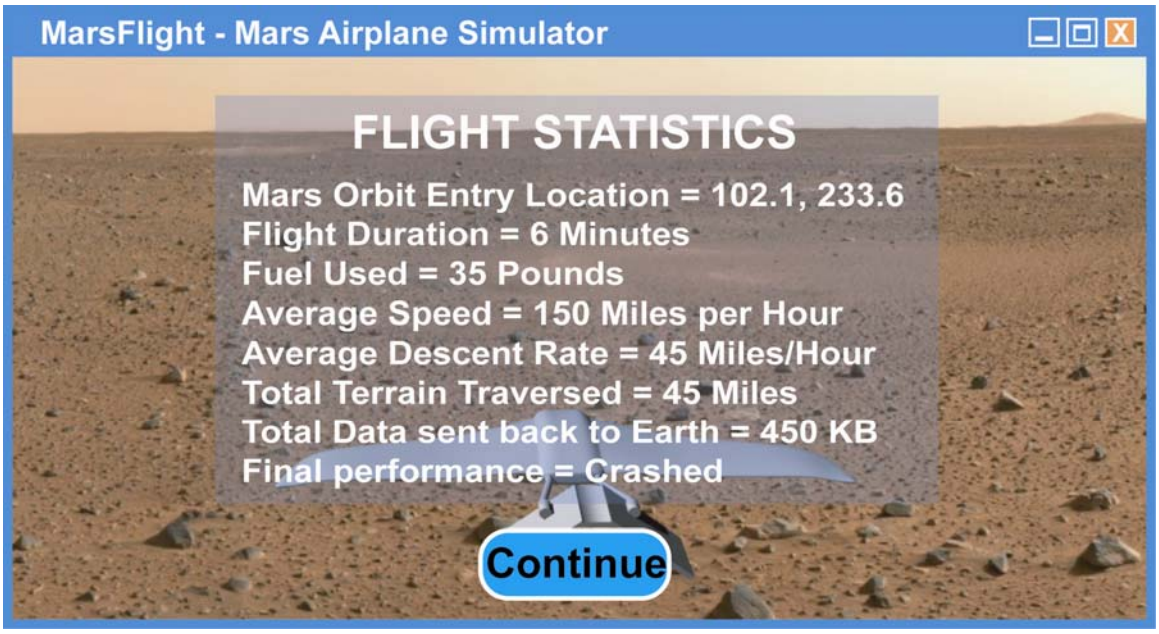


Figure 19 – Statistics summary

Note: The Flight Statistics screen will contain a freeze-frame of the final image from the simulation.

5.5.9.2 Magnetic Field mapping display

This display is utilized in conjunction with the MarsFlight curriculum and it simulates an actual mission that could be conducted using the Mars Airplane. The actual concept is very simple. The magnetic field around Mars is far different than it is on Earth. Since Mars has many areas of varying positive and negative magnetic fields, a compass taken to Mars wouldn't function properly. The magnetic field of Mars has been mapped by previous Mars Spacecraft so you would simply utilizes a data file that contains a magnetic field value for each latitude/longitude as well as if it is positive or negative. This file should be in a standard ASCII file format so we can update this data as more accurate data exists. Then as a user tracks over an area in either the Interactive test flight or autonomous mission, the magnetic field data for that area will be stored in

another file (The user magnetic field data map) which is then printed out in this display or on a printer as shown in figure 19.

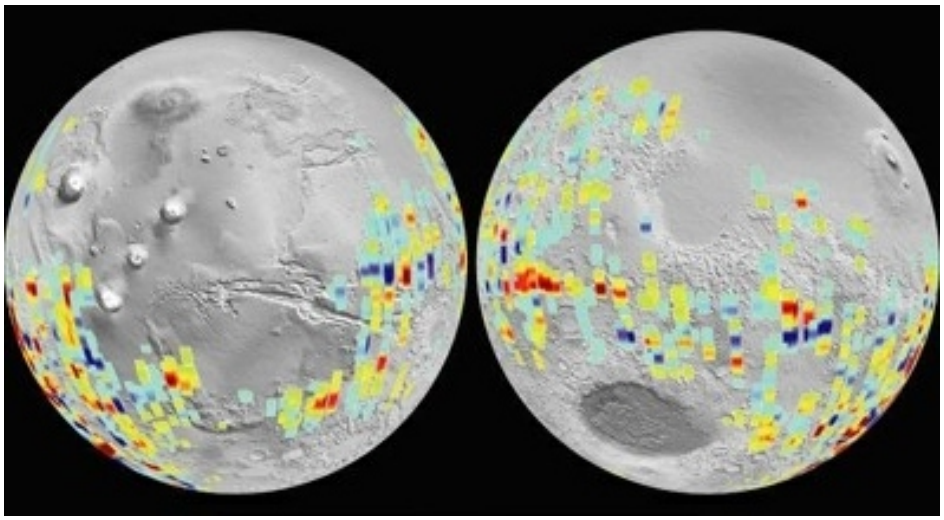


Figure 20 - Magnetic Hotspots on Mars

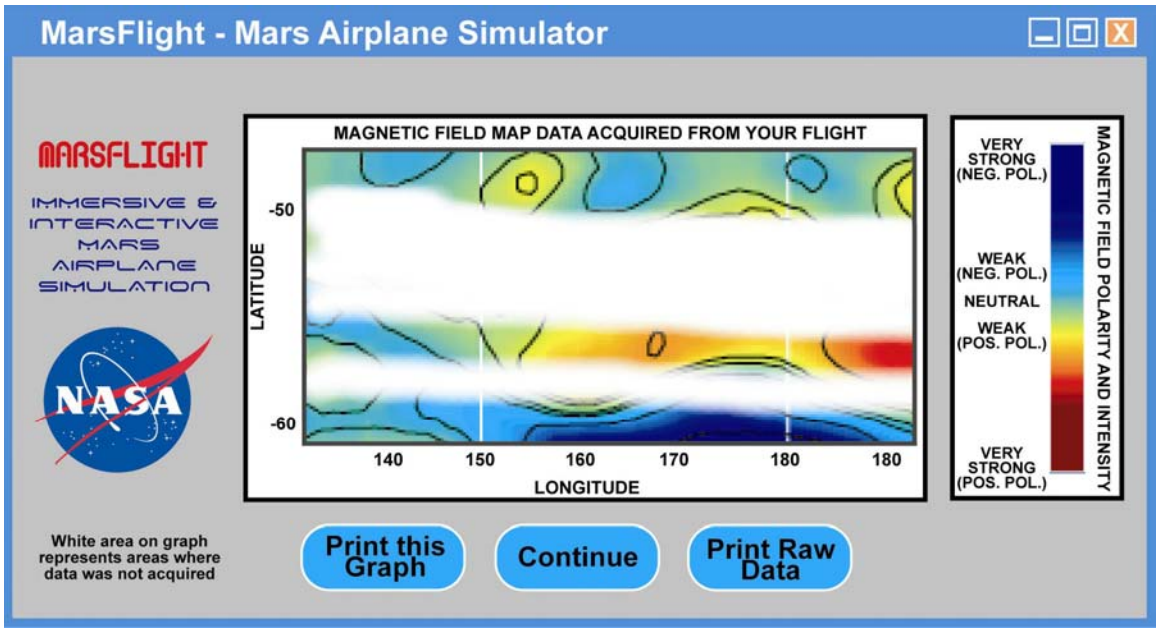


Figure 21 – Magnetic Field map display

5.5.9.3 Print Certificate

Provide the ability to print a certificate with the following data on it:

1. A framed backdrop having some cool render of the Mars Airplane
2. Congratulations text at the top and a bank for the student's name
4. A graph showing the magnetic data acquired during student's flight
5. A summary of flight statistics

5.5.10 Reset Simulation for Next User

After the guest selects “Continue” on the statistics display, MarsFlight will reset all variables and conditions (As if the software was first run) and increment the usage counter by 1 and then will return to the Intro. Screen/Main Menu waiting for a new guest to begin.

6. MarsFlight Exhibit

Please note that the Mars Airplane exhibit will be developed by a dedicated exhibit company and NOT the software developer. This description is only being provided as a source of information to help the software developer understand one of the ways the MarsFlight software will be used.

Special Note – The developer is not responsible for the development of the MarsFlight Exhibit. This description in this section is only being provided to inform the developer about the exhibit that will be used with the software they develop.

This section is being provided to describe our exhibit setup a bit more. A special exhibit has been designed to perfectly compliment the “MarsFlight” software. See Figure 20 as you read the description that follows …

The “MarsFlight” exhibit concept is to develop a Mars Airplane Mission Control Console. The exhibit would contain a 42” Plasma screen that would serve as the primary display window.

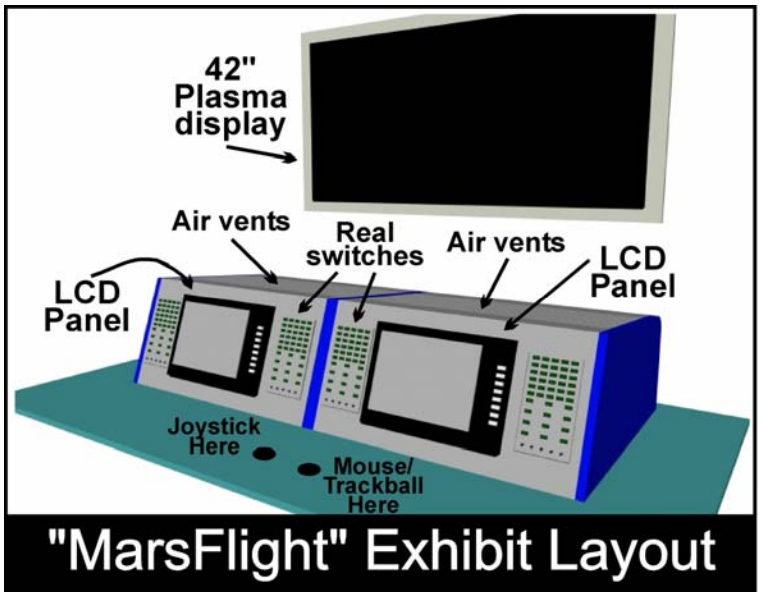


Figure 22 – MarsFlight Exhibit Layout

The pilot would be sitting at the mission control console that would house two LCD panels, a joystick, and a trackball. The LCD panels would be used to show mission data that is retrieved during the flight and the flight characteristics of the Mars Airplane. The joystick and trackball would be used to control the Mars Airplane during flight. Actual functioning switches and blinking lights should be utilized in the consoles to greatly increase realism. As can be seen on the diagram above, there are four banks of switches/lights on the two consoles. It is suggested that we devote each bank to a different Mars Airplane subsystem. For instance, we could have one bank of lights/switches devoted to the Mars Airplane propulsion system, another to the Power generation system, another to the scientific instruments, and another to Communications (with Earth). These switches and lights, however will only be used for show and will not interact with the simulation being run in order to reduce complexity and cost. The plasma screen and consoles should fit inside a tent-like enclosure that contains Mars Exploration images on the outside of the enclosure. The tent-like enclosure would contain bold, inspiring graphics on the outside related to the Mars Airplane mission and the major goal of this simulation which is education. The tent-like enclosure would not only attract guests to the Mars Airplane exhibit but it would also shield the displays from bright sunlight which could minimize visibility. This exhibit should fit in 3 or 4 crates with wheels that can be transported with a standard truck to make transportation easy. The crates would contain the two consoles themselves, the computer system used to operate the exhibit, and the tent enclosure. The exhibit must be able to be setup by a maximum of two people without the aid of machines such as tow motors.

7. Special Features for Exhibits

7.1 Demo Mode

A demo mode is to be added to MarsFlight to demonstrate the operation of the software for guests and attract them to the simulation. The demo mode must briefly demonstrate the complete operation of the software starting with the MarsFlight intro/splash screen and then ending with the statistics screens. The “Demo mode functionality shown in figure 21 describe the operation of the demo mode and the demo mode block diagram describe the demo mode flow. The demo mode should purposely be designed to be as exciting and as thrilling as possible.

7.2 MarsFlight Usage Counter

MarsFlight will be capable of generating a usage file that will record and tally the number of users that flew “MarsFlight” by date and time.

This file will be in standard ASCII format that can be read by any computer without any software. This usage log file is useful to NASA and museums who

wish to keep track of the exact number of users who fly “MarsFlight” each day to use for reporting purposes.

The format of this usage file is as follows …

Date, Time, # of flights = (Flights)

Thu Sep 18 19:46:30 2003 - # of Flights = 6
Thu Sep 18 21:22:30 2003 - # of Flights = 26
Thu Sep 25 06:15:35 2003 - # of Flights = 20
Thu Sep 25 06:21:17 2003 - # of Flights = 45
Thu Sep 25 19:01:25 2003 - # of Flights = 25

Since the data will be tallied at the time the simulation is exited, it is possible to have a few entries per day if the software was exited and restarted several times that day.

Demo Mode Functionality (Rules)

- Demo Mode will start automatically after a user-preset time (Configured in the startup screen) of no mouse/trackball activity (Ie. No button presses or physical movement). Demo mode can also be started immediately upon pressing the “d” key.
- Demo mode will be exited (And Marsflight will return to the intro/start screen … waiting for a new user) upon any mouse/trackball activity (Ie. A button press or some physical movement). Demo mode can also be termininated upon pressing the “d” key. Note that the same key “d” is used to start and terminate Demo mode. .
- Each cycle of demo mode should not last longer than 60-65 seconds unless absolutely necessary and should be repeated indefinitely until stopped using a method described above.
- While demo mode is running at a major exhibit, we will only have a short time (Perhaps 15-30 seconds) to capture a guests interest and encourage them to want to fly the simulation. For this reason, it is important to design the demo mode sequences to be as exciting and captivating as possible.
- Demo mode must reproduce the exact operation of the displays and views as during a “interactive” run conducted by a guest in whatever display environment and resolution is currently configured at the time of start.

7.3 “Keyboard Not Required” at Run Time

As with all previous simulations we've developed, the entire simulation can be fully enjoyed using only the Joystick and mouse/trackball. During the operation of an exhibit, the Keyboard is only intended for use by the Teacher/Simulation Operator for startup, shutdown and configuration and is not intended or required to be used by the student. All functions required to fully operate the simulation must be implemented using the joystick, mouse/trackball, or any of the buttons on both of those devices.

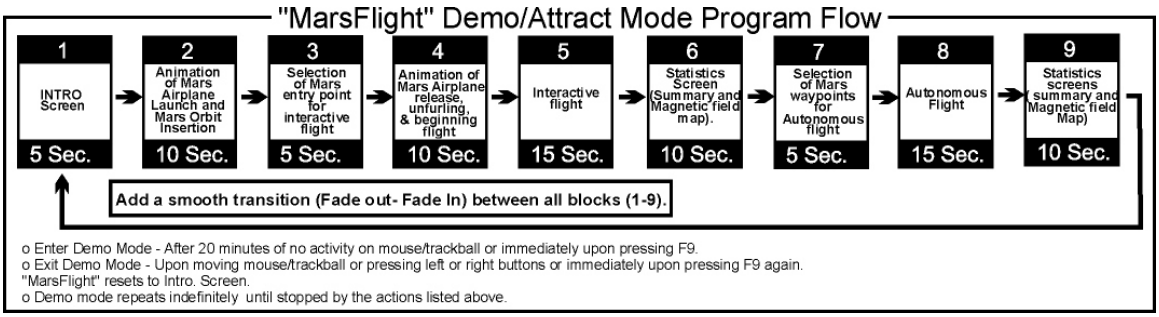


Figure 23 – MarsFlight Demo mode program flow

7.4 Exhibit Mode of Operation

The setup/configuration screen will enable the teacher/simulation operator to better configure the simulation for usage as an exhibit. The setup/configuration screen will enable you to skip various functions such as animations or help screens, or data entry screens (And use default values) in order to facilitate fast and efficient usage at exhibits.

8.0 Setup and Configuration Screens

There are two types of setup and configuration GUI screens and their associated data files.

The **configuration screen** may be displayed prior to startup and will enable the user to configure the software's technical parameters. These are parameters that will not usually change very often so the usual course of action will be to just click "OK" to accept the current configuration. These parameters will be stored to a file so they don't have to be re-entered each time. If a change is necessary, the user can make the change easily and intuitively and this will cause the new parameters to be written to a file called "mf_config.txt". Just like the usage statistics file "marsflight.txt", this file must be easily readable/changeable with a text editor as well even though the usual method for making a change will be through the MarsFlight configuration GUI just prior to startup. Some of the configuration changes that could be made in the configuration gui and/or stored in the configuration file "mf_config.txt" could include such parameters as the time limit to wait before demo mode is entered, and the screen arrangement, resolution, and field of view. Even parameters that aren't shown in the

configuration GUI at startup can still be stored in the “mf_config.txt” file. For instance, if the MarsFlight display arrangement is changed interactively using the PC/Windows convention for positioning and resizing windows, this data could be stored in the “mf_config.text” file even though it isn’t configured via. The configuration GUI at start-up.

The **setup screen** will enable the user to interactively change the operating parameters of the software and the setup file “mf_setup.txt” will store this configuration so it doesn’t have to be re-entered each time. These are parameters that will usually change quite often and include such things as the time limit, the program flow settings, a fuel level, etc. An example of a setup screen is shown in figure 22 is still under design.

The following options are currently defined …

Flight Realism – This determines the realism (Difficulty) of flying the plane. While we are most interested in the “Authentic” realism, we want an easier mode to be implemented for younger or less-experienced fliers.

Launch Date – This data determines the location (And orientation) of the Earth, Mars, and sun (And perhaps the satellites orbiting Mars) for the purpose of providing realistic lighting, shadows, and enables realistic operation of the communications network display (among perhaps other things as well).

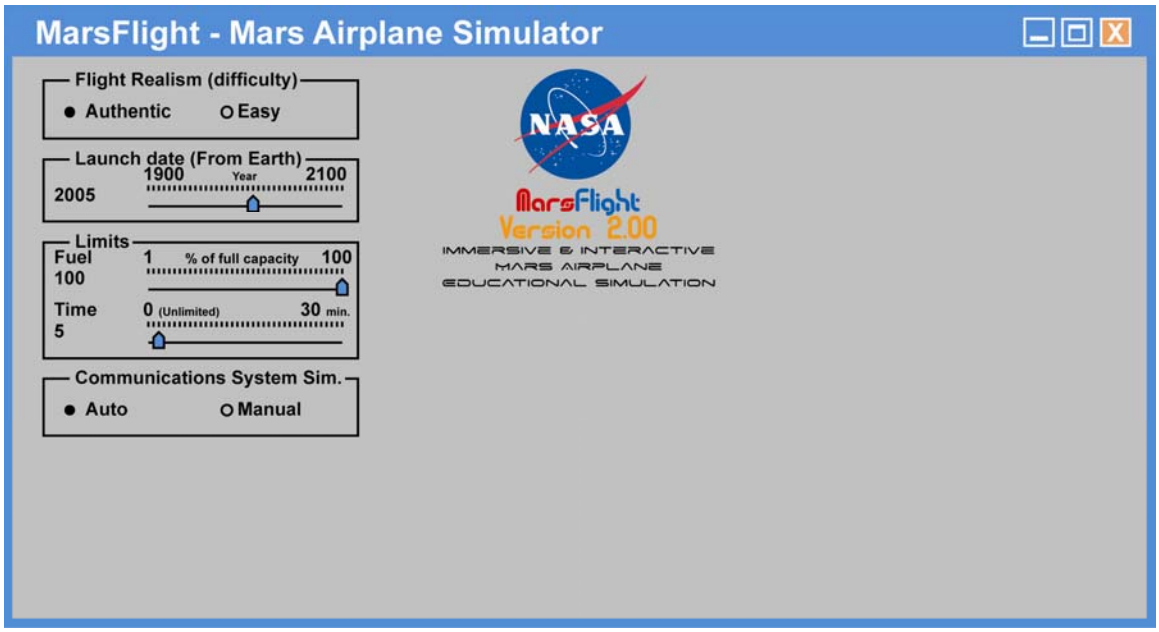


Figure 24 – Setup screen (Work in progress)

Fuel Limit – While the quantity of fuel is fixed, this settable option varies the percentage of fuel in the tanks at the start of the simulation.

Time Limit – This settable option sets the overall time that the simulation is run. At the end of time, the flight will end; the statistics screens will be displayed.

Communications System Sim. – This settable option determines if the computer or the user controls which Mars-Orbiting satellites relay the radio signal back to Earth, and what the transmitter power is.

All of this data should be stored in a file so that any changes do not have to be re-entered every time the software is run.

NOT SHOWN – Mars-Orbiting satellite orbit configuration for three satellites or several preset satellites.

The settable options included on the setup screen will be jointly determined by the developer and NASA throughout the software development.

9. MarsFlight Curriculum

MarsFlight has been designed specifically with a multitude of curriculum goals in mind.

9.1 Overview

The Primary usage for MarsFlight will be to involve middle and high school students in a fun learning activity based upon a flight of an airplane on Mars. During the initial planning of MarsFlight and the development of this design and reference document, a number of features were designed into the MarsFlight software that would enable educational curriculum to be developed. These features are explained in this section.

9.2 One user or two users working cooperatively

MarsFlight provides the ability to involve two users working cooperatively to plan a mission, and then fly it over the surface of Mars to obtain the greatest amount of data they are able before they crash, or before fuel, their batteries, or time runs out. Both students would sit at the control console either on separate monitors or on a big single monitor. One user will be the Navigator, and the other user will be the Systems Engineer. See below for job responsibilities …

Navigator – Navigate the Mars Airplane above the surface using the joystick, and control the airplane's speed using the throttle. The navigator has the responsibility of looking what's ahead and helping to assure that the airplane doesn't crash or venture into an area of low density. If data is being acquired too fast, the Systems engineer may request that the pilot slow down a bit until the data buffer onboard the airplane can empty.

Systems Engineer – Monitor the communications system using the Lower/Right console display (The Power, Propulsion, and communications system). Control the communications system using a mouse/trackball by adjusting transmitter power, and selecting which of the three Mars-Orbiting satellites are used to relay the data back to Earth. The System's engineer's primary task is to keep an eye on the satellite currently relaying data back to Earth, and on the data buffer currently displaying the usage percentage. In order for a satellite orbiting Mars to communicate with the Mars Airplane, it must be visible (In the line-of-sight) to the airplane. Therefore, if the System's engineer looks at the current position of the satellites and determines that the signal from one of them is about to be obscured by the planet Mars, or another satellite, then they will have to switch to another satellite that is in the line-of-sight of the airplane. Not doing so could risk having the buffer full up which could ultimately lead to loss of data. The systems engineer also needs to observe the distance between the "currently-communicating" satellite and the airplane. Since greater distance reduces the data rate, the student may decided to switch to another satellite that is in the line-of-sight but is closer to the airplane and thus offers a lesser distance for the radio signals to travel and a higher data rate. Obtaining a higher data rate may also be desired if the data is being acquired at a higher rate. However, a higher data rate also places a strain on the batteries so if batteries are low, a higher data rate may not be as desired. The System's engineer will also have the ability to control the power of the transmitter. Since a higher power transmitter causes a higher data rate, the user could raise the power of the transmitter if the onboard buffer is getting full.

If only one user is available, the Power, propulsion, and communications simulation can be set to "Auto" in the setup screen and this will cause these decisions to be made by computer rather than requiring the user to make them. In this situation, the user only needs to concentrate on flying, and on avoiding areas of lower density.

9.2 Curriculum Ideas

Note – this section is being provided as reference only since the software developer WILL NOT be required to develop curriculum.

MarsFlight has been designed to be a learning tool for middle and high school students. A comprehensive curriculum will be developed to guide students through activities involving MarsFlight. Listed below are some ways that students can learn from MarsFlight.

1. Compare flight on Earth with Flight on Mars
2. Learn how the movement of the aero surfaces on the Mars Airplane affects its flight path
3. Learn how the magnetic field on Mars differs from the magnetic field on Earth.

4. Graph the magnetic field for the area the student flies over
5. Work cooperatively to accomplish a common goal
6. Experience some of the stress actual mission controllers and scientists experience when working on a space mission
7. Learn about satellite communications
8. Observing and identifying features on the surface of Mars from high above
9. Discuss areas on Mars that would make good landing spots for a future human Mars expedition.