Interactive Design Environment

Tools for Facilitating Communication and Collaboration Among Universities on Projects Related to a Mars Mission

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1.0 Introduction

The HEDS-UP program is comprised of student groups from many different universities across the United States working independently on various aspects of the grand objective – a manned mission to Mars. The inherent value of the program is in the nature of the students working in it. Students offer a different perspective on an existing project. Their contribution is in bringing the off the wall ideas to the table, among others. Students are unbounded by tradition and precedents in methodology. This enables them to approach the problem from a unique angle. They have the potential to bring fresh ideas and new dimensions to the overall project, thus contributing something original rather than mimicking existing projects. With proper facilitation the HEDS-UP program can become an evolutionary dynamic environment in which ideas are proposed and tested under pressure and those with sufficient merit survive. Moreover, the incredibly cheap price of student labour gives the HEDS-UP program enormous potential to provide a substantial and lasting contribution to the Mars mission.

The potential value of the projects completed by the HEDS-UP universities is limited by the geographical and academic separation of the universities, the short term nature of the projects, and insufficient input from NASA. If communication exists between the universities at all, it is minimal and limited to the conference. The projects are limited by the school term and the turn over rate of the participants is exceedingly high with an influx of new students each semester. This means that much of the work from previous semesters is lost as it is improperly passed on, incompletely understood, and consequently disregarded. There is no consistent method employed across the universities for storing the information and making it accessible to others in the field. Moreover the projects suffer from a dislocation from NASA itself. The insufficient feedback and inadequate resources for the projects limit their technical content. If a means of overcoming these limiting factors is found, the Mars mission project could then fully take advantage of the enormous pool of talent that currently exists within the HEDS-UP program.

The combined projects offer the very real possibility of contributing to a mission to Mars without simply replicating what NASA is already fully equipped to do. Our design proposal set about to solve these existing problems so that the HEDS UP program can flourish. Better communication between university projects would lead to proposals that can be better integrated into an overall mission design. They would be able to consider a broader context and work within those constraints. Communication is of particular use to students working on mutually dependent or similar projects. The exchange of ideas rather than facts would greatly further the conception of design projects.

It is important to keep the work of previous semesters. This is not to suggest that it will all be correct or even useful, but it provides a basis which further work can develop and give a greater understanding of the mission constraints. In fact, learning from past mistakes could be one of the most valuable assets to come from the compilation of such a body of work. This past work could provide an even greater foundation if it were broader, and therefore a compilation and organisation of all the projects proposed throughout the HEDS UP program would be immensely useful for creating a more complete picture of all the intricacies and implications of a mission to Mars.

When the projects are fully linked to NASA they can become technically sound and, as such, gain validity as serious design projects. They contain ideas that need a solid grounding in data in order to be considered and also give a more immediate indication as to their feasibility. An easy channel of communication would enable the exchange of data between project designers and those at NASA that have the pertinent information. This is especially useful as the Mars mission is highly specific and the number of experts in related fields is acutely limited.

Problem Statement: Our aim was to develop a tool that overcame the barriers of geography and limited communication to provide an interactive design environment which fostered academic communication and continued project development in order to further a mission to Mars.

2.0 Methodology

The organization of UC Berkeley's class into separate but concurrent design projects was highly similar to that of the HEDS-UP program and suffered from the same limitations. The Interactive Design Environment was created to meet the needs of the class and aid communication between the groups, compile past work in an accessible and useful manner, and provide a bridge between interdependent groups. Additionally it was designed to be efficient and easy to use with specific tools to meet different needs such as chat capabilities, a method of posting ideas, and storage and retrieval functions. Moreover, specific applications, namely MarsHOT (Habitat Optimization Tool) and CAPS (Computer-Aided Power Simulator), were integrated into the project to allow easy and direct comparison of projects in the fields of habitat and power, respectively. In conjunction, these tools create an interactive forum for the exchange and development of concepts with applications to analyze design proposals in a consistent manner

Direct parallels can be drawn between the structure of the HEDS-UP program and UC Berkeley's class. HEDS-UP comprises a collection of universities working on separate projects. Our class mirrored this on a smaller scale, as it was divided into several project groups working on differing but related aspects of the Mars mission and, as such, suffered from many of the same limitations faced by the HEDS-UP program. The IDE was designed around the class with the intent of overcoming those problems and also with the foresight that it could be scaled up to cover the entire HEDS-UP program. This would enable easy communication not only among related groups at one university, but also among groups at different universities.

The IDE is based on Internet technologies, therefore scaling it to service larger groups located disparately is not even necessary -- it is already capable of doing so. It cannot, however, scale indefinitely. At some point a system must develop whereby each university or research center will have its own IDE, or perhaps multiple IDEs, each with its own database, and access to all IDE databases through a common set of protocols.

2.1 IDE Methodology

Easy and efficient information exchange is vital to scientific advancement. The IDE was created with this in mind. The proposed design is one that provides an interactive web site that houses a suite of tools for data storage and retrieval and for collaboration and communication on many different levels. Additionally, specific tools created to aid design project work are built into the IDE to increase its functionality. The site and tools therein are easy to use and require minimal time to learn. This is a general design principle which any good software project should follow, and it is especially important in the case of tools such as those the IDE provides, because easy access facilitates better communication.

No special software or hardware is required to use the IDE beyond the minimal requirements for accessing the World Wide Web. Custom software is especially cumbersome when wide deployment, as is the intent of the IDE, is involved. There are multiple concerns, the foremost being the requirement that the software be made available for multiple platforms (e.g. PC, Mac, UNIX). By necessity this adds complexity to the software in both development and maintenance, and drastically increases the amount of time required for each.

The IDE's design is simple and utilitarian. Fancy graphics, sounds, and other bells and whistles, while nice, tend to increase complexity of design and add greater load to the system without adding much functionality. Such features were to be used sparingly, and only if they added considerable functionality. This has the additional benefit of enabling the IDE to be accessed by users with limited access to the Internet, such as older software or limited terminal capabilities.

The design was developed with the needs of students in mind. There already exist products which mimic many of the functions of the IDE, but most of these products are targeted at commercial users, and thus assume greater capabilities of both the server and client computers than can reasonably expected from students with limited means. These off-the-shelf products also do not tend to integrate well, meaning that the users must learn multiple interfaces, and must often manually transfer data from one tool to another.

Multiple design elements have been created that facilitate communication between participating universities or other concerned parties and aid development of their design projects. These are similar in both application and implication. The *chat system* provides immediate text-based communication between individuals. The ideas proposed can be posted, with optional complimentary graphics, for further comment on a *virtual whiteboard.* The refinement of the designs requires a foundation. This is provided by a *digital library* which houses all contributions made, both published and not, to a research or design effort. These tools are supported by a software infrastructure built around a database subsystem. They provide both communication and collaboration abilities for the user through a customized web server. The IDE also has a simple and consistent interface that meets the user needs, as detailed above, while presenting a solution to the problem faced.

2.2 CAPS and MarsHOT Methodology

In addition to the communication and collaboration tools discussed previously, specific design tools have been developed that demonstrate the usefulness of the IDE for specific design projects. These two applications, MarsHOT (Mars Habitat Optimization Tool) and CAPS (Computer-Aided Power Simulator), demonstrate the use of the IDE as a forum for comparison between specific projects. As such they can provide a consistent basis for determining an idea's feasibility as part of a design project and highlight areas for further refinement and development. Most importantly, the applications themselves can be further refined and improved upon as the problems facing the Mars mission continue to be identified and defined.

Along with the communication and exchange of ideas, design teams require a consistent format for making comparisons between proposed and existing designs. Without such comparison ability it is a purely subjective decision as to whether they are feasible. Two such tools have been developed and integrated into the IDE in order to provide such a yardstick for comparison. MarsHOT and CAPS are specific applications that provide mathematical analyses of design missions based on specified parameters and independent variables. There was tandem research and development of these tools, because in order to make a comparison, one needs a standard with which to compare. The control variables, equations, and overall concepts for these tools were determined by research conducted in the fields of power and habitat design.

These communication tools can be used on a local all the way though to a global level. They were developed to support research groups and their utility is not limited to a single university. Their integration into the IDE assists research and design efforts when the participants are in disparate geographical locations. These tools are the text-based chat system and the virtual whiteboard.

3.0 Results

3.1 Chat System

The chat system allows participants to meet online to collaborate in real-time. Any participant in the chat system may create a channel (or "chat room") which other participants can join, subject to the access restrictions the creator of the channel specifies. All users present in a chat room receive all messages directed to the room, but users may also direct private messages to a specified person or persons. This facilitates open as well as confidential communication.

A special function of a chat room’s integration in the IDE is the ability of participants in a chat room to select documents from the IDE's digital library to present to others in the room. The chat system is integrated with the database functionality of the IDE, and because it is accessible using a standard web browser, it can easily provide the ability for multiple users to view the same document at the same time and share hyperlinks to external sites on the World Wide Web. The participants also have the option of having the chat system record their chat session into the database for future reference by themselves or others.

3.2 Virtual Whiteboard

The chat system is, however, inherently limited by both its immediate nature and its confinement to the printed word. The virtual whiteboard was designed to overcome the necessity of real-time participation by all involved. It allows contributors to post ideas for further perusal at a later date. Additionally, it provides the ability to present not just text, but graphical representations of ideas, through what have been dubbed "virtual cocktail napkins," in recognition of the many great ideas born on said medium. These small drawings are composed and submitted at the same time to compliment the textual explanation of an idea.

The virtual whiteboard facilitates discussion between participants who infrequently or never meet face-to-face, but unlike the chat system, it is for extended discussions occurring over a period of hours or days. Any registered IDE user may create a whiteboard or participate on any active whiteboard. The whiteboard's functionality is made available through the World Wide Web, therefore any person with web access may view the whiteboards in the database. Access controls are also provided so that the whiteboard's creator may restrict the ability to view or contribute to the whiteboard should this be desired.

A virtual whiteboard, shown in figure 1, appears very much like a real whiteboard, with bulleted lists of ideas and scattered sketches, but underneath lies a powerful threaded messaging system. Participants can associate hyperlinks with their entries on the whiteboard, referencing entries within the IDE database, such as documents from the digital library, transcripts of past chat sessions, archives of mailing lists, or even other whiteboards. Other whiteboard participants can reply to an idea posted on the whiteboard with a comment of their own, causing a hyperlink to appear below the idea.

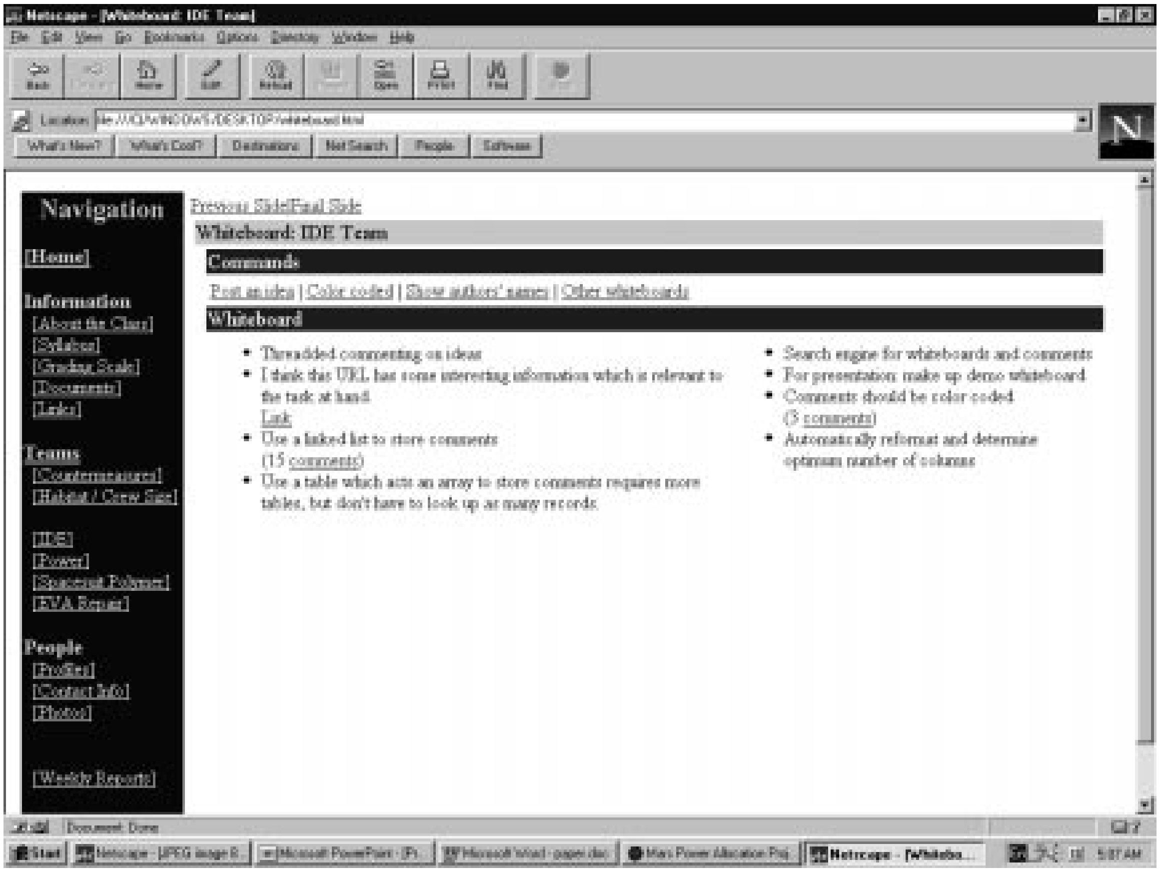


Figure 1. Screenshot of Virtual Whiteboard.

The functionality of the virtual cocktail napkins is provided by a small application (applet) which is executed within the user's web browser. The applet is written in the platform-independent Java programming language, meaning that any computer user with a standard modern web browser would be able to use this tool.

3.3 Digital Library

There is a recent trend moving away from the traditional distribution of paper documents toward their distribution in digital form. As such, it is becoming clear that traditional libraries are no longer the most efficient mechanism for the archival and dissemination of large volumes of information. When the documents a researcher is interested in are available in digital form, the time involved in manual retrieval is eliminated by instant electronic retrieval at the researcher's desktop.

The digital library, shown in figure 2, includes not only published material but all contributions made to a project, in a variety of media. These contributions could include transcripts of chat sessions, completed whiteboards, and additional postulations. The initial, most basic form of the usable digital library consisted of a collection of documents on computer media and a user interface for document retrieval. Extensions to the functionality of this library include categorized listings of documents, keyword searching, and hypertext cross-referencing of footnotes and endnotes.

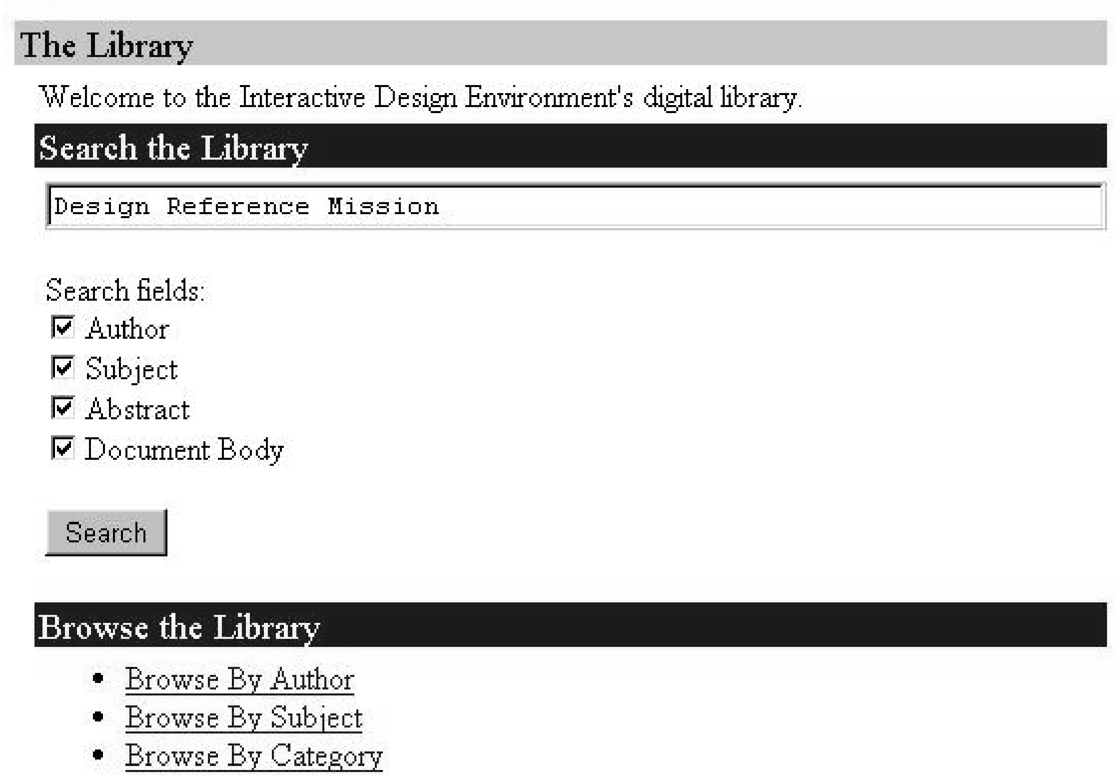


Figure 2. Screenshot of Digital Library.

The IDE digital library includes these extensions, and goes one step further to extend the degree of interaction. Registered IDE users are able to annotate documents and to provide hypertext links to other related documents in the library or external to the library (e.g. World Wide Web addresses). Documents within the library can also be referenced from an IDE chat session or virtual whiteboard.

Access to the library is through a web-based interface. The actual library itself is stored as a Structured Query Language (SQL) database using the database backend of the IDE maintainer's choice, as the IDE's modular nature provides a layer of abstraction between database accessories (i.e. the document library interface) and the communication between the IDE and the database backend.

The interface provides the user with the option to browse the library by author, by category, by date of document publication or inclusion in the library, or to search by any of the aforementioned listings or by keywords within the documents. From there, based on the user's selection, a list of matching documents is presented along with the option to narrow or redefine the search.

Upon selecting a document, the user is presented with the best possible presentation of the document. If the document is in HyperText Markup Language (HTML), it is immediately presented in that form, but if it is available only in a format or formats which cannot normally be displayed by a vanilla web-browser, such as PostScript (PS) or Portable Document Format (PDF), a hypertext link to download the PS or PDF version of the document is presented, along with a short explanatory paragraph about the document's format and possibly an abstract or other short description of the document if available. It is also possible that a document is present in multiple formats, e.g. the original document in PDF format, and an HTML version created by a PDF-to-HTML translation program. In these cases, an IDE user's configured preferences determine whether the HTML document, or a list of document formats to select from, is presented.

Documents presented in HTML format provide the reader with the benefits of hyperlinks to referenced sources and annotations, as mentioned earlier. When presenting documents in formats not renderable by web browsers, the digital library provides any annotations or hyperlinks associated with the document as part of the web page providing the download link to the document file. For registered users of the IDE several hyperlinks to digital library functions for annotating the document and creating hyperlinks to other relevant documents are included in the document presentation. If the user is currently engaged in a chat system conversation, the ability to present the document to other chat participants is also available.

3.4 Supporting Infrastructure

While IDE's user interface provides a convenient way for users to interact with the system, it cannot function without sophisticated support software to provide low-level functionality. The most immediate support facility is the HTTP module, which is in essence specialized web server software designed to provide a common interface for the other components, or modules, of the IDE. The other facility provided is the database module, which provides uniform methods for storing and retrieving information in the IDE's SQL database.

The HTTP module is designed to be compliant with the HTTP/1.1 draft specifications[cite], though it does not implement some portions of the specification's functionality which are not applicable to the IDE system. The module provides the interface between the user's web browser and the other functional modules and handles much of the necessary text parsing and composition related to the HTTP protocol.

The database module provides an interface for modules to read from and write to the IDE's database. Most of the work required to access the database backend is done within the database module, which has the benefits of both simplifying the writing of other modules and making the database module a replaceable component. There are numerous third-party SQL database implementations, each one having its own advantages and disadvantages, so it is desirable for changing the SQL implementation to be as easy as possible. Database access abstracted through the database module, so it is only necessary to modify this module when the implementation is changed, instead of every module which accesses the database.

3.5 MarsHOT

Mars Habitat Optimization Tool, or MarsHOT is a specific application of the Interactive Design Environment. It was designed as a tool for determining the most suitable habitat design out of the hundreds that currently exist. While there are many different proposals, the designs have certain features in common that enable direct comparison between existing and proposed designs. MarsHOT is written in Excel, making it simple to use, and it additionally may be downloaded from the class web site. As such, it is easily accessible to a multitude of users and provides a consistent basis for comparison of habitat designs. Moreover, the program is designed such that it can be improved upon by its users. Its principal limiting factor is the data supplied to it. As the design proposals are refined using MarsHOT, they can contribute to its further particularization and enhance its utility.

A prominent feature of all the designs is the great attention paid to the mass of the habitat. Mass is a premium commodity in the Mars mission due to the enormous amounts of fuel needed to transport the payload safely to the planet. Therefore, mass is used as the optimization criterion against which the proposals are measured in the program. For the purposes of this program, the habitat was divided and analyzed based on the following subsystem: habitat structure, crew accommodations, consumables, CELSS, communications and information systems, medical equipment, rover, airlock/ports, radiation shielding, power generators and science equipment. Also, due to the basic nature of the analysis, the program does not make a distinction between interplanetary and surface habitats.

Design Reference Mission

19 Independent Variables	
Length of Mission (Days)	**879**
Number of Crew Members	**6**
Height Per Deck (m)	**2.32**
Minimum Volume Per Crew Member (m^3)	**90.00**
Diameter of Habitat (m)	**7.50**
Aspect Ratio on End Caps	**0.50**
Material Used for Habitat Design	**6061-T6 Aluminum**
Ultimate Strength of Material (Pa)	**3.103E+08**
Density of Material (kg/m^3)	**2712.64**
Pressure Ports	**4**
Rover Type	**Minerva (Unmanned)**
Recycling Efficiency for Water	**0.9**
Water Buffer	**100**
Recycling Efficiency for Oxygen	**0.8**
Oxygen Buffer	**50**
Shielding Type	**Storm**
Acceptable Radiation Dose	**23.00**
Power Supply	**DRM**
Internal Pressure (Pa)	**6.70E+04**
Factor of Safety	**3.00**

Fixed Portions of Habitat	
Exercise Facility (kgs)	**770**
Communication/Information Systems (kgs)	**213**
EVA Airlock System (kgs)	**3000**
Doorlock (kgs)	**1370**
Scientific Lab (kgs)	**1770**
Medical Supplies (kgs)	**700**

Ramifications of Variables	
Material Thickness (m)	**0.0024**
Exterior Surface Area of Habitat (m^2)	**149.27**
Mass of Unreinforced Exterior (kg)	**983.56**
Mass of Reinfroced Exteror (kg)	**1081.91**
Structural Mass of Empty Hab (kg)	**1622.87**
Number of Decks	**5**
Total Minimum Volume	**540**
Radius	**3.75**
Consumables	**17976.12**
Other Water (kg)	**79110**
Potable Water (kg)	**14767.2**
Total Water Used on Mission(kg)	**93877.2**
Total Amount of Water per day (kg)	**106.8**
Total Water Needed (kg)	**9487.72**
Food (kg)	**7383.6**
Oxygen (kg)	**5274**
Total Amount of Oxygen per day (kg)	**6**
Total Oxygen Needed (kg)	**1104.8**
Crew Accomodations	**552**

The inputs into MarsHOT are 19 independent variables, length of mission; number of crew members; height per deck; minimum volume per crew member; diameter of habitat; aspect ratio on end caps; material used for habitat design; ultimate strength of material; density of material; pressure ports; rover type; recycling efficiency for water; water buffer; recycling efficiency for oxygen; oxygen buffer; shielding type; acceptable radiation does; power supply; internal pressure; and factor of safety; which parameterize the design. The relationships between these variables and the mass of each subsystem have been derived by researching established habitat designs. The NASA Design Reference Mission, Zubrin's Mars Direct, and the Stanford International Mars Mission were the principal designs used. In its simplest function, MarsHOT can take all 19 variables as input and calculate the mass of the designed habitat. From these, small changes may be made to see their effect on the overall mass. As a more powerful use, the program may take a number of the variables as input along with specified mass and solve for the optimum configuration of the remaining variables using Excel's "Solver" function.

3.5.1 Subsystems

In order to calculate the total mass of a habitat it is divided into 10 subsystems. Relationships between the mass of each of the subsystems and the independent variables were derived by examining pre-existing, accepted designs.

Habitat structure

The structure of the habitat, defined as the exterior and interior structure and their supports, is a significant portion of the overall mass. We assume it to be separate from the shielding. However it is difficult to fully incorporate the structure into the MarsHOT application. This is because the interior structure of the habitat is subject to many environmental and architectural constraints that can not be easily represented numerically. Thus the assumption is made that the interior structure will have a mass equivalent to 50% of the exterior structure mass. This estimate is consistent with the habitat design of the NASA Design Reference Mission.[i] Also, of the many materials that can be used to create both the pressure vessel and the supporting structure of the habitat, the data for three known materials, aluminum 6Al/4V; titanium 22-19-T8; aluminum 6061-T6, was entered. Each safety factor of the three was chosen to represent the use of a reliable material in difficult environmental conditions[ii].

The structural mass is therefore calculated as follows. The external surface area is determined from the radius, height, and ellipsoid aspect ratio, and the material thickness is determined according to the formula for a thin-walled pressure vessel, given the material properties, factor of safety, and internal pressure defined by the user. The external area is then multiplied by the material thickness by the density of the material to give the mass for the un-reinforced shell. The mass of reinforcements is taken to be 10% of this calculated value. As stated above, the mass of the internal structure is taken to be 50% of the mass of the reinforced external structure. The total structural mass, therefore, is the external area times the material thickness times the material density times 165%. In summary:

$m'_s = pAt$
$m_r = (0.01)(m'_s)$
$m_{is} = 0.50(m_r + m'_s)$
$m_s = m'_s + m_r + m_{is} = 1.65\ m'_s$.

Crew Accommodations

The crew accommodations are those items or systems that uphold the standard of living for the astronauts. The crew accommodations specified in this report are neither necessary to the immediate survival of the astronauts, nor do they directly contribute to the scientific goals of the mission. The overall mass estimate for the entire crew accommodations, based on the Stanford International Mars Mission with a crew of six, is 1320 kg. Of that, the mass of the exercise facility remains fixed at 770 kg while the remaining mass varies linearly with crew size. The resulting equation for accommodations is
m = 770kg + 92N when N is the number of crew members. The additional 92 kg for each crew member includes the galley/wardroom, crew quarters, and personal hygiene facilities.

Consumables

Consumables, comprising the food, water, and oxygen that the astronauts will use during the mission, depends on the number of crew members and the length of the mission. Therefore, in the calculations, the parameter used was mass per person per day. However, a factor that greatly affects the mass of consumables is the efficiency with which the habitat is able to recycle them. Each of the major manned-missions to Mars has established their own estimate for the mass of the consumables. By averaging the recommendations it was determined that each person uses 2.8kg H_2O, 1.0kg O_2, and 1.4kg food per day. Additionally, hygiene requirements add 15kg/day per person.

Life Support System

The life support system includes an air revitalisation subsystem, water purification subsystem, and waste management subsystem. Each of these subsystems must be capable of supporting the crew and yet not be too heavy. This balance depends on the recycling efficiency of each subsystem. The NASA design reference mission specifies a mass of 4661 kg for the life support system to support a crew of six people. The Stanford mission and the Mars Direct mission both allocate a mass of 3000 for the life support system. Using these total masses as guidelines, a total mass penalty of 750 kg per crew member was determined for air, water and waste subsystems. Although there are many other aspects of the mission that will influence the life support system, the relationship was simplified to a linear one between the mass of the life support subsystems and the crew size.

$m_{eclss} = 750N$

Communication and Information System

The communication and information systems are the critical interfaces between the crew on Mars and Mission Control on Earth, as well as between the crew and various computer controlled systems of the habitat. The overall mass of the combined system is estimated at a constant 0.3 metric tonnes.

3.6 CAPS

There are many different permutations of power generation systems, each of which is limited in output by different parameters of safety, cost, longevity, mass, volume and necessary redundancy. CAPS was created to efficiently analyze the feasibility of each proposed power generation system for function on Mars. CAPS, shown in figure 4, is a user-friendly and effective application, written in Delphi, a windows object based programming language, that enables the user to set the usage and supply restraints of a power system and run a balance to determine necessary power supply component. The consistent format of the analysis allows for easy comparison of existing and proposed missions. The utility of CAPS is that it can be refined and adapted as technology develops. It provides an analysis based on the information provided, and thus can improve as this data becomes more specific and accurate. The program is an application of logic, which can be used as a tool for further research by other students.

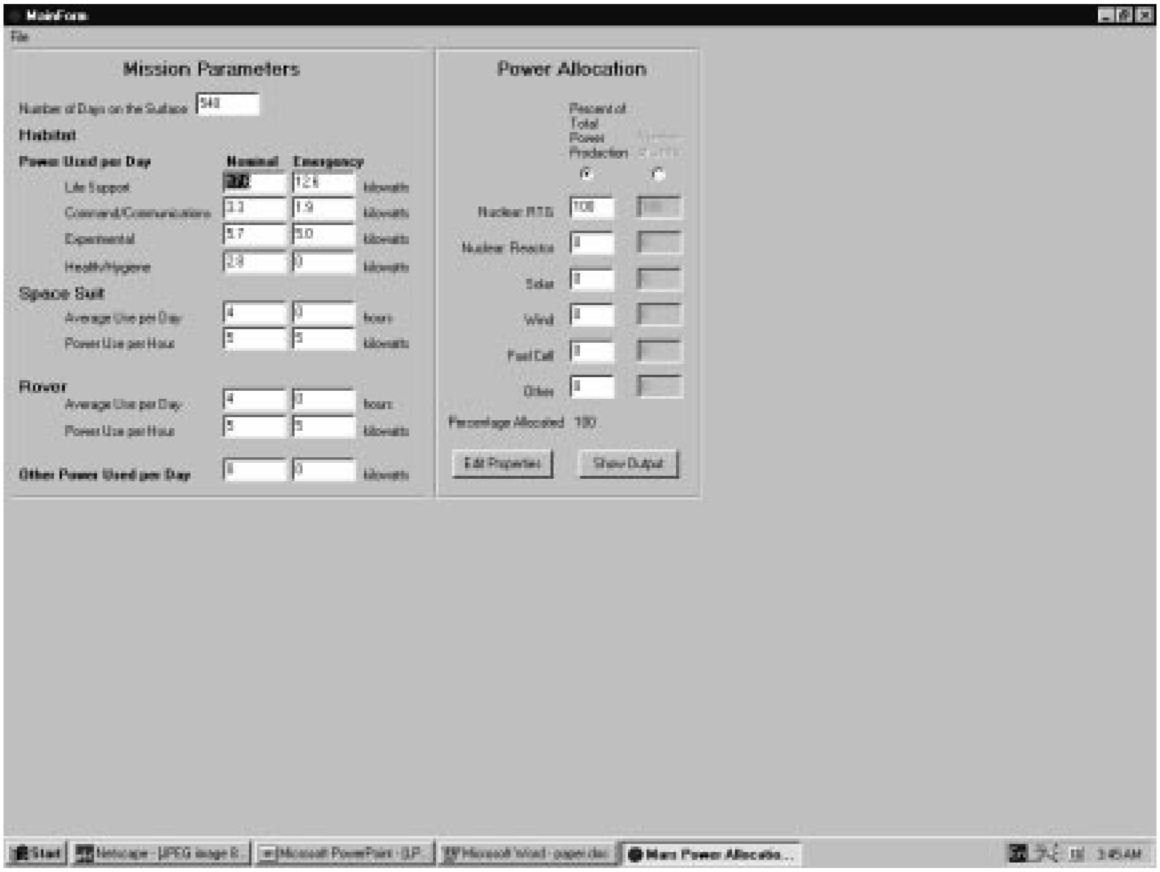
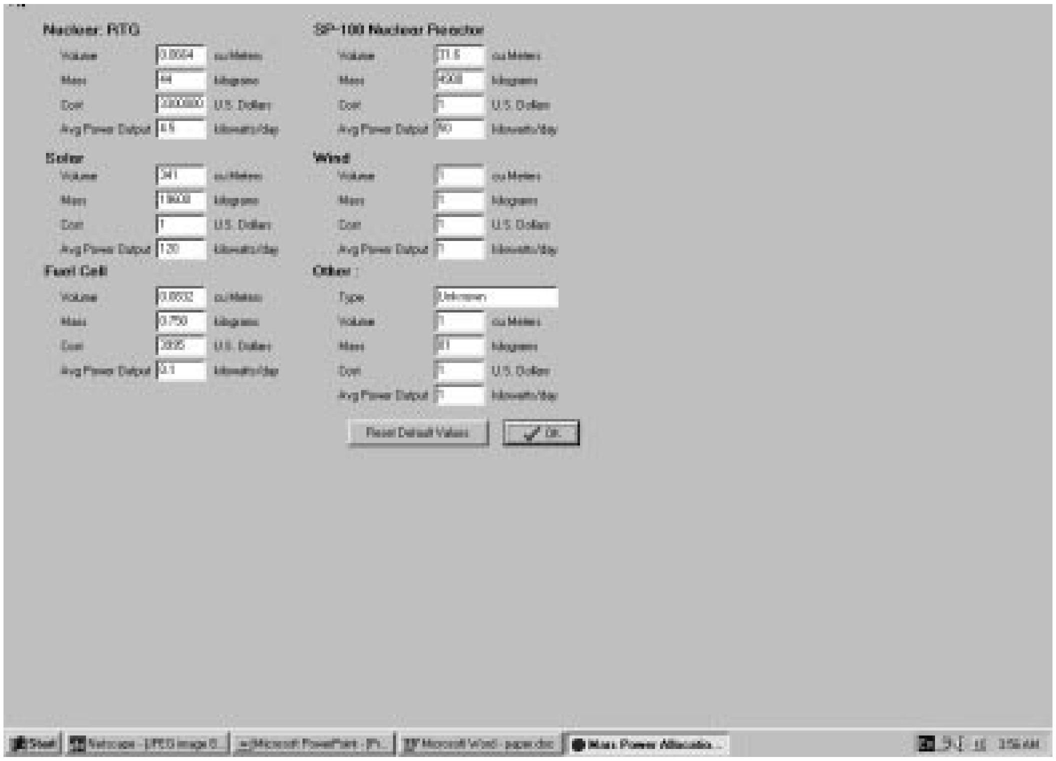


Figure 4. Screenshot of CAPS main screen.

A power generation system is constrained by the many mission parameters of the power generators and consumers. The nature of the Mars mission is such that humans need to live and work in a hostile environment. Therefore, power is needed to compensate for every aspect for this and provide a local inhabitable environment, namely the habitat. This means that there are an enormous number of power consumers. For simplicity's sake they have been grouped into five principal categories: life support systems, scientific equipment, rovers, space suits and communication equipment. The specifications of the mission are confined by the parameters of the consumers, which consist of average power use per day, peak consumption at any given time, and minimum emergency power needs. These values are different for every power consumer and are incorporated into the program as default values. The defaults for both consumers and generators were determined by the extensive research conducted over the course of the project.

Similarly, the power generators have constraints that the CAPS program must take into account. There are certain basic needs that any power source must meet: it needs to be brought from Earth, function safely on the planet, and optimize the cost/benefit ratios. The transport of the generator to Mars greatly limits its mass and volume, because at the heaviest extremes the payload could not be physically supported by the rockets and above certain values the power generators are no longer fiscally viable. Longevity and



reliability of the generator are also vital factors in its functioning on Mars. The habitat will be completely isolated from Earth and thus there is no possibility for replacement or aided repair of any generator. The power system as a whole must be able to function safely to preserve the well being of the crew and it must be able to meet the peak requirements of the power consumer as well as satisfy the baseline life support system requirements with at least 50% redundancy.

As yet, there is no ideal power source that meets the needs of power generation as well as meeting the transport limitations. Therefore, known power sources were researched and evaluated for a Mars mission using the criteria discussed previously. The power sources researched were nuclear, solar, wind, and fuel cells, and their data provided the technical framework for the application – a basis upon which the calculations can be made.

The CAPS interface allows users to easily change the parameters of power allocation for the mission and redefine the properties of the power generators. Specifically, a user can change the average use of each consumer and any and all of the parameters of each power generator such as efficiency, cost, and power output. The parameters for each power generation system are changed on an secondary screen shown in figure 5. Given these constraints CAPS will calculate the total mass, cost and volume of the system of each generator, as well as cost/power, mass/power and volume/power ratios for each of components. The basic ratios provide a consistent basis for comparison of possible missions.

Figure 5. Screenshot of CAPS, Production parameters form.

The user can also specify the components of the system by setting the number of units of each generator to bring, or by setting a percentage distribution. The analysis provided, shown in figure 6, will not only display the ratios discussed, but also determine whether each of the power suppliers would be able to accommodate the entire emergency power requirement. If any of these is in excess or is insufficient, the analysis will show by how much, and also calculate, in the event of an inadequate power supply, how many supplemental units would need to be brought to cover the emergency requirements.

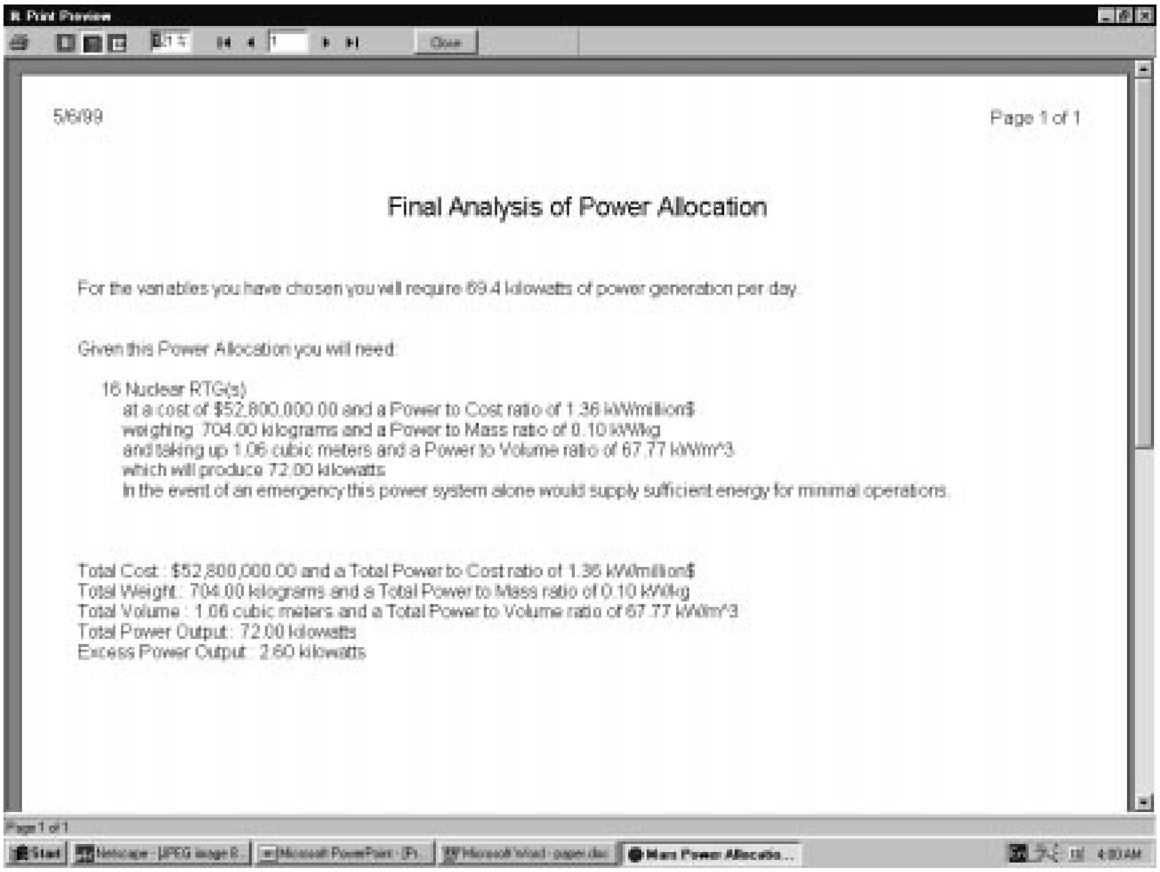


Figure 6. Screenshot of Final Output from CAPS.

CAPS is a dynamic tool, limited by the current understanding of the mission parameters. As these parameters and their constraints become more clearly defined, CAPS can be developed and refined. It currently provides an analysis based on the research conducted thus far. As the design project for the Mars mission develop through the contributions of those students involved, the program will adapt to provide a more detailed and comprehensive analysis of proposed power generation systems. The program is an application of logic, which can be used as a tool for further research by other students. It is an invitation to others to extend and particularize it. It is not complete because it presumes only to be a beginning.

4.0 Conclusion

Due to the composition of the HEDS-UP program, specifically being made up of dynamic, enthusiastic, and creative minds, the potential exists for production of design projects that will significantly aid in NASA's mission to send a human to Mars. The usefulness of the IDE to overcome barriers such as geographic dislocation amongst design partners and transmission of knowledge from one semester's project to the next has been demonstrated in UC Berkeley's "To Mars By 2012" class. The use of the IDE, easily scaled from its current single university implementation to a HEDS-UP wide system for communication, collaboration and design would propel HEDS towards that goal.

The IDE as it is currently designed is a very useful tool for enabling communication and collaboration among research groups and researchers. However, for the most part, it is only a design. The most immediate goal for the IDE project is to complete implementation of the components already designed. While this is in progress, the design of the next version of the IDE will occur in parallel.

The first major item for consideration in the next version is how it can be made better suited for use by larger groups of participants. Facilities must be designed to allow designation of administrative authority to local leaders (i.e. Berkeley-based users of the IDE should be under control of someone at Berkeley, while users based at NASA Ames should be under control of someone at Ames, and so on).

Considerations for distributing the IDE into multiple semi-autonomous servers scattered among the participating universities and research centers should also be made. This will allow for redundancy, ensuring that each center can access its own database should network problems temporarily disrupt communication with the other sites, and increase scalability by distributing processor load and consumption of storage space across multiple computers.

Finally, the current version of the IDE, once fully implemented, should be tested with actual users and observations should be made on how well the IDE improves their productivity. Comments from the users on how to improve the IDE should be solicited as well. Modifications should be made to the designers of the next version to take these data and comments into account. This applies especially to the design tools MarsHOT and CAPS which are available to any user or interested party to examine, critique, or modify. Consider this an invitation to the members of HEDS to begin to develop an organizational paradigm focused on interaction and collaboration with the aim of making HEDS a forum for university input directly into the design of a NASA led, manned mission to Mars.

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[i] Design Reference Mission Version 2.0
[ii] Machinery's Handbook