POTENTIAL CAPABILITIES AND USES OF AN INTEGRATED DATA LOGGING DEVICE DURING A HUMAN MARS EXPLORATION MISSION

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During the 2003 field season at the Mars Desert Research Station (MDRS) in the Utah desert, a functional prototype for an integrated data logging device (referred to in this paper as a "Datalogger") for assisting science data collection during planetary exploration extra-vehicular activities (EVAs) was tested by crewmembers of Expedition One (Feb. 15 – Mar. 16). The Datalogger prototype consisted of software running on a laptop PC and a 20 x 4 character LCD display with 16-key alphanumeric keypad. Two configurations of the display/keyboard interface were tested: a handheld version and a chestplate-mounted version. The software functionality of the Datalogger prototype consisted of GPS coordinate recording, audio comment recording, and EVA organization capability.

The Datalogger prototype was tested during six simulated Mars exploration EVAs by biologists and geologists. Users completed questionnaires following the EVAs. Based on the experiences of the Datalogger users, insights into possible uses and desired characteristics of an integrated data logging device for geological and biological field science research during future human Mars exploration EVAs are presented. Finally, the role of telematics and geomatics in shaping future planetary exploration is briefly discussed.

INTRODUCTION

During future human Mars exploration missions, astronauts will conduct Extra-Vehicular Activities (EVAs) to gather data to support geological and biological research efforts. As is known from lunar and Earth-orbit mission experience over the past several decades, EVAs are the most risky portion of space activity after launch and landing events.

Thus, an important consideration for Mars exploration EVAs is to provide astronauts with effective tools for increasing the efficiency of their activities and maximize the scientific data gathered. One such tool is an integrated data recording and display device, which in this paper will be termed a Datalogger. Previous research on Dataloggers for Mars exploration EVAs has been conducted at the NASA Haughton Mars Project.[1]

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Related research on mobile agents was also performed by Dr. William J. Clancey during the 2003 Mars Desert Research Station (MDRS) field season.[2]

A prototype Datalogger device was developed by the Mars Society of Canada to explore possible functionality and interface options for a device that could be used on future human Mars exploration missions. This prototype Datalogger was tested during a research expedition to the Mars Desert Research Station (MDRS) in southwest Utah, U.S.A. in February/March 2003.[3] During this research expedition (Expedition One), the prototype Datalogger device was used by geologists and biologists in the conduct of Mars analog research under simulated Mars EVA conditions, where analog spacesuits were worn and the research carried out in a Mars analog environment.

This paper is divided into several sections. The first section will describe the prototype Datalogger device hardware and software developed for the Expedition One research expedition. The next section will describe how the Datalogger was used at MDRS, present a sample of the data collected and discuss results obtained from the user questionnaires. Following this, possible uses and desired capabilities and characteristics of an integrated data logging device for geological and biological field science research during future human Mars exploration EVAs will be presented. Finally, the role of telematics and geomatics in shaping future planetary exploration will be briefly discussed.

PROTOTYPE DESCRIPTION

The Datalogger prototype was developed as a low-cost functional prototype data logging device testbed for testing a variety of functional capabilities and operator interface concepts during simulated human Mars exploration EVAs in a Mars analog environment. Results of these tests can then provide input into future development of actual data logging devices for human Mars exploration missions. The Datalogger prototype was developed and implemented by a team of volunteers from Mars Society Canada and Mars Society USA. The main components of the Datalogger system are the Central Processing Unit (CPU), Interface/Display Unit (IDU), assorted data collection peripherals and the Datalogger software.

Datalogger CPU

For the primary data processing and storage functions of the Datalogger prototype, a PC-based architecture was adopted. The standardization and commercial off-the-shelf (COTS) nature of such hardware minimized compatibility issues and allowed the majority of the team's time to be spent on the operator interface and functional capabilities which are the primary focus of the testing.

An initial attempt using PC-104 circuit boards to construct a small, rugged CPU was abandoned due to technical difficulties. Laptop PCs were then chosen for the Datalogger prototype due to their availability, although there was some concern that they would not be rugged enough to withstand the EVA conditions to be encountered at MDRS.

However, the Dell Dimension laptop used proved more than adequate to the task during testing at MDRS.

The CPU receives input from the serial port (GPS/keyboard) and microphone, and provides output over the serial port (GPS/display), parallel port and speaker (i.e. audio prompts and system status). The parallel port is used to implement serial device switching via a simple switching circuit. This allows multiple data collection devices to be connected to a single serial port on the PC.

Interface/Display Unit

Two different configurations of the Interface/Display Unit were constructed – a handheld version and a chestplate version. A 20-character by 4-line LCD display with backlight and a 16-key alphanumeric keypad were common to both IDU configurations.

The handheld IDU consists of a commercial off-the-shelf (COTS) plastic enclosure containing the LCD, keypad, and a display power switch. This IDU is carried in a pocket of the EVA suit until needed by the user. To operate the handheld IDU requires the use of both hands (i.e. one hand to hold the IDU while the keypad is used with the other hand). With this configuration of the IDU, a smaller plastic enclosure for housing serial port switching circuitry and batteries is attached to the EVA suit. Power to the display can be switched off when the display is not in use.

The chestplate IDU integrates the Datalogger interface and display elements into a chest-mounted custom-machined aluminum enclosure designed for the MarsSkin, a prototype analog Mechanical Counter-Pressure (MCP) EVA suit developed by James Waldie at RMIT University in Melbourne, Australia. In addition to the Datalogger LCD, keypad, and display power switch, the MarsSkin chestplate contained additional LCD displays for monitoring of suit vital functions (see Figure 1). Serial port switching circuitry and batteries were contained within the enclosure.

Figure 1 Datalogger Chestplate Interface/Display Unit

In both IDU configurations, the display/keyboard interfaces to the PC via the serial port switching circuitry. The LCD served as the main display for the Datalogger (the laptop screen is not used as the laptop is mounted to the EVA suit backpack, with text output controlled via the Datalogger software. The alphanumeric keypad allows data input and navigation of the user interface.

Data Collection Peripherals

For the Datalogger prototype used at MDRS, the primary data collection peripherals were a Garmin eTrex Global Positioning System (GPS) unit for obtaining positioning data and a headset with microphone for obtaining audio comments. The eTrex connects to the Datalogger via the serial port switching circuitry.

Datalogger Software

The Datalogger software consists of the Red Hat Linux operating system (minimum kernel version 2.4) and custom software coded in ANSI C/C++. The operating system choice was made with consideration to the level of hardware and software support (e.g. available for Intel and PowerPC CPUs, available compilers, software libraries, and documentation), stability, and cost. The custom software is as close to POSIX standards as possible; the software should thus compile for other platforms but some source code modifications may be required.

The custom software consists of several independent daemon processes that control voice recording, the display unit, and GPS position download. The daemons are managed through a controller process. The daemon processes communicate with the controller process using System V inter-process communication (IPC) message queues. Communication is bi-directional, and messages are passed between the controller and the daemons in the form of a data structure which includes the identification of the sending and receiving process, the type of message (e.g. keyboard input), and a string containing the actual data block. Data is then written out to the internal storage device. The display software provides the capability to define, via configuration files, a set of menu pages containing both fixed and variable text fields. Variable text fields can be configured to display a variety of available system data, such as time, current position, distance to next waypoint, or other desired information.

A novel feature of the Datalogger software is an EVA organization capability, which recognizes a hierarchical EVA structure consisting of multiple sites, which can contain multiple features at which multiple samples can be taken. An initial hierarchy of sites/features/samples can be pre-configured for a given EVA; however, the user is free to add sites/features/samples as the EVA progresses.

Data gathered using the Data Logger is stored in multiple files in a format resembling the XML standard. This allows data to be exported and used in other applications, such as a relational database and GIS applications. Each data entry is timestamped. User actions are also logged to facilitate testing and debugging.

Upon starting the Datalogger unit, the operating system is loaded and the Datalogger software (all the daemons and the executive) is automatically started as part of the boot-up script. Peripherals are initialized and the Datalogger main menu is displayed. When the human operator enters a command via the keyboard, the command is transmitted from the keyboard listening daemon to the controller, which then acts on the message. If required, the event is logged and the data stored. For example, if the operator commands an audio comment to be recorded, the controller commands the daemon process that controls the audio to begin recording. Audio from the microphone is then digitized and stored on the hard drive. When the operator indicates that the comment is completed, the controller commands the audio daemon process to end the recording. The audio daemon process compresses the recorded audio into MP3 format and returns a message when the compression is completed. When the EVA ends and the user returns to base, collected data is downloaded to a file server via a serial or network connection.

METHOD AND RESULTS

During the first week of Expedition One, final integration and testing of the Datalogger prototype in the handheld display configuration was performed. As well, the LCD display and keyboard were integrated into the chestplate of the analog spacesuit known as MarsSkin, provided by the Australian members of Expedition One, and testing of the Datalogger prototype in the chestplate display configuration was successfully completed. The addition of a camera for taking digital photos was deferred to a subsequent version of the prototype due to technical difficulties.

During the subsequent three weeks, the Datalogger prototype was used on six EVAs to assist in the collection of science data. Table 1 lists the EVAs on which the Datalogger prototype was used, the display configuration used for each EVA, and whether the EVA focused on geology or biology.

Table 1
SUMMARY OF DATALOGGER FIELD TESTING

EVA #	Datalogger Type	EVA Science Type	EVA Location
010	Handheld	Geology	Amphitheatre Wash, White Rock Canyon
031	Chestplate	Geology	White Rock Canyon
032	Handheld	Biology	White Rock Canyon
038	Chestplate	Biology	Dry Wall Canyon
049	Chestplate	Geology	Uranium prospect
058	Chestplate	Biology	Sandy hill, Kent's Reservoir

The following process was followed for each of the six EVAs:

1. Prior to the EVA, the Datalogger laptop was configured by an engineer, which involved assigning a unique number to the EVA, setting up a directory for data storage, and ensuring that fresh batteries were installed;
2. During suit-up (either at the MDRS Hab or in the Rover prior to depressurization), the Datalogger was mounted to the suit backpack, all peripherals were connected, and the Datalogger was activated;
3. The Datalogger was used to record GPS position, audio comments, and EVA organization information (e.g. sites, features, samples) during the course of the EVA;
4. Upon return to the Hab, the recorded data was offloaded from the Datalogger laptop onto the Hab server for storage and processing;
5. The Datalogger user completed a questionnaire to assess the ease of use of the Datalogger in comparison with operating separate data collection devices to gather the same data, and to allow provision of comments and feedback.

Logged Data

The Datalogger data recorded from each EVA consisted of a time-stamped series of GPS coordinates and audio comments. The level of each event within the data organization hierarchy established by the user was also recorded (e.g. EVA:EVA31, SITE:20000001). To illustrate the type of data recorded, an excerpt from EVA#31 is provided in Table 2. Full access to the Datalogger data sets is being provided to the investigators participating in each EVA in order to track how this data is used in their research.

Questionnaire Results

Quantitative results are not very relevant for the Datalogger usage questionnaire, since the number of subjects is low (n=6) and the questionnaires were completed at different times during the expedition (more than a two-week span). Therefore, no statistical quantitative analysis can be performed on this data.

Sentences such as « In general, biologists like this capability of the datalogger better than geologists do. » would rely on the opinion of a very small sample. No significant pattern appeared regarding gender, science type, or datalogger type. Frequency of use was not correlated in any significant way with the rating of usefulness by the user.

However, a general description of the results can be provided as follows.

1. **GPS Display Capability –** All subjects (five) who evaluated this item found that the GPS function was very useful (mean mark: 4.8 on a scale of 1 to 5) and unanimously found it more convenient to use than the regular hand-held GPS.
2. **Audio Recording Capability –** The audio function was found to be very useful (mean mark: 4.8), except that two subjects out of six found it no more convenient than using a regular tape recorder

Table 2
DATA EXCERPT FROM EVA 31

Time (UTC)	Event Type	Data Level	Event Details*
21:31:33	Audio	EVA:EVA31	"This is EVA31 on February 25th, 2003. EVA with Melissa Battler, Nancy Wood, and Rocky Persaud as one team and the other team is EVA32 but they're sort of joining us for this EVA so we're kind of combined. We're looking for a suite of igneous rocks up and down a stream channel of the White Rock Canyon area and we're planning to collect a complete suite of samples at three rock sites as well as measure about 50-100 cobbles of igneous materials at those three sites each."
21:35:30	GPS	EVA:EVA31	Northing 4247073.0 m Easting 520335.7 m Altitude 1343.7 m
21:36:32	GPS	EVA:EVA31	Northing 4247072.1 m Easting 520335.8 m Altitude 1345.8 m
21:37:30	GPS	EVA:EVA31	Northing 4247068.4 m Easting 520332.8 m Altitude 1333.9 m
21:37:53	New Site	SITE:20000001	
21:38:30	GPS	SITE:20000001	Northing 4247070.6 m Easting 520332.3 m Altitude 1333.7 m
21:48:30	GPS	SITE:20000001	Northing 4247070.6 m Easting 520323.4 m Altitude 1333.6 m
21:49:15	Audio	SITE:20000001	"Sample: 7 cm"
21:49:23	Audio	SITE:20000001	"11 cm"
21:49:30	GPS	SITE:20000001	Northing 4247071.5 m Easting 520323.7 m Altitude 1335.1 m
21:49:52	Audio	SITE:20000001	"9 cm"
21:50:09	Audio	SITE:20000001	"12 cm"

* GPS co-ordinates in UTM format, NAD27 Datum. Transcription of audio comments was performed manually

3. **Data Organization Capability** – The data organization capability was found less useful than the GPS and audio (mean mark: 3.2), and two subjects out of five found it *less* convenient than laptop-based organization prior to the EVA (note however that the other three found the reverse – that the Datalogger was more convenient for data organization).

Qualitative results (results from open questions) can give further hints on how the datalogger could be improved to fit the needs of scientists in the field. The following suggestions for improvement were received:

- provide improved boot process (easier for user);
- provide improved design and ergonomy (integration to chestplate, cables, sight of screen, headset);
- provide automatic continuous wireless transfer of data to rover / base (hab);
- provide faster access to data once back at hab;
- provide more easily viewable and accessible hierarchical data tree on screen.

The first two comments are easily understood given the stage of development of the Datalogger prototype and the focus of the current investigation (i.e. on functionality and user interface, rather than on providing a complete Mars-ready Datalogger). The remaining three comments refer to additional functionality for the Datalogger system (which includes both the Datalogger itself and related systems for configuring the Datalogger and accessing and processing the Datalogger data). Plans for future versions of the Datalogger system address these comments and include the capability of wireless data transfer, voice recognition for activation of Datalogger functionality, data processing software to allow fast and user-friendly access to the recorded data post-EVA, and a graphics-capable user display.

FIELD SCIENCE CONSIDERATIONS

One of the big issues that will face field scientists on the surface of Mars will be that of workload. The physical and mental demands of working in a space suit will be high, operating instruments and tools will be difficult, and time limits enforced by life support capacity of suits will always be pressing. Any technology that minimizes workload and increases the ability of the field scientist to acquire and interpret data needs to be carefully evaluated. Data collection requirements and objectives of specific scientific disciplines need to be considered in this evaluation process. This section explores the needs of field geologists and biologists conducting Mars exploration EVAs and proposes desirable capabilities and characteristics of a Datalogger system to address these needs.

Geology Usage

Field geology, whether on the Earth, Moon or Mars, requires three main types of operation:

1. **Establishing the architecture of a site.** This requires understanding the spatial distribution of different geological materials and their orientation, geological

structures and their orientation, and landforms. It is also vital to establish the timing relationships between different units and structures through the stratigraphic succession and over-printing relationships. Collecting this information requires the recording of observations by the field geologist, instruments to capture position and orientation (such as a GPS, a compass and a clinometer, field sketching of relationships, and photography). This type of operation is often iterative and may be carried in a scouting mode at a number of sites in succession with little further investigation. All documentation is normally captured in a field note book, less commonly on tape. Sites of interest may be immediately studied in more detail or referenced for return at a later period.

2. **Documentation of geological materials and units.** This consists of two broad types of operations, measuring detailed spatial information, and documenting textural and compositional aspects of the geological materials. Detailed spatial information includes the orientation of structures and features, such as layering, faults, fractures, and flow indicators (measured on earth with a compass and clinometer), and unit thicknesses (measured on earth with a tape measures, extendable rules, or Jacobs staff in conjunction with a clinometer). Compositional data includes details such as hand specimen mineralogy, field tests for minerals such as carbonate and phosphate (not applicable to field work on Mars because they use water-based reagents), and data from hand-held instruments to measure radiation (geiger counters, scintillometers, gamma-ray spectrometers), magnetic susceptibility, and multispectral data, either from passive radiometers obtaining ground truth for air or space-borne systems, or active systems such as a Portable Infrared Mineral Analyzer (PIMA).[4] Textural data includes feature such as grain and crystal size, variation in grain and crystal size, preferred orientations, volcanic sedimentary or igneous structures, overprinting mineral growths, and fossils. Level of documentation of materials and units varies according to the degree of investigation. Only general aspects may be collected during a scouting while highly detailed descriptions will be collected as a precursor to sampling or during systematic traverses.

3. **Detailed sampling.** This is carried out on targeted samples for specific analysis back at a laboratory, such as detailed geochemistry, petrology, palaeontology, geochronology, or paleomagnetism. After collection each sample is assigned a unique number and bagged. Sample numbers and any supporting information is recorded.

Some additional field geoscience techniques should be noted in passing, these being drilling and geophysics. Shallow core or auger holes to depths of a few meters are a useful technique for studying unconsolidated material such as soils and sediments. Deeper drilling requires heavy, vehicle mounted machinery and is used only to obtain data that cannot be obtained any other way. Subsurface geological data is processed in much the same way as surface data, though determining the architecture, documentation of units and materials, and sampling. Geophysical surveys also require specialized equipment. For example the Apollo 17 mission carried instruments to collect passive and active seismic data, measure atmospheric composition, detect gravity waves, carry out a gravity traverse, measure surface electrical properties, and determine soil mechanical properties.[5] Geophysical instruments record their data digitally and these days almost always download data through a direct interface or via a data link. Although used by field geoscientists, the recording of data from most geophysical instruments is not an issue for astronaut Dataloggers. The exception would be the handheld instruments for collecting magnetic, radiation, and spectroscopic data mentioned above.

On Mars, given the limited dexterity of gloves and limited visibility in a helmet which makes it more difficult to keep track of numerous items of equipment, a data logging system that collects and stores observations, measurements and images offers considerable potential for reducing workload and speeding up fieldwork. Analogous situations on earth where such systems would be useful include underwater or polar and high-altitude environments. However the proviso is that such a system must be as light as the other systems it replaces, easy to use, reliable, and the data must be stored in an easily accessed and useful form. These facts cannot be over emphasized, as many technological innovations for the field scientist are not reliable, simple, or light.

Datalogger Experience at MDRS – Geology EVAs. The following observation was received from the Expedition One chief geologist regarding usage of the Datalogger prototype usage during EVAs involving geological exploration, and illustrates the importance of integrating the Datalogger into the mission information infrastructure:

> The prototype Dataloggers used at MDRS during Expedition One were backpack-mounted units controlled through a chest panel and voice. They recorded voice observations and the GPS coordinates of stations. With practice they proved an effective way of collecting and storing data although, in common with other experimental equipment, they were not fully reliable. They proved successful in minimizing the time taken to record observations and positions by eliminating the need to write things down, thus freeing the geologist's hand for other tasks.
>
> One major drawback of the Datalogger prototypes was accessing the data. During a 4 hour simulated EVA a field scientist might record up to an hour of observations and numerous different sites. To review the observations would require the scientist or another researcher to listen to all the recordings, which would take as much time as the original recording. It is also difficult to cross reference the GPS co-ordinates to the descriptions. A third drawback, compared to written notes, is that it is impossible to amend an observation. Observations recorded about a particular feature in a field notebook can be later corrected or added to by marginal comments or footnotes. This was not possible to do with the current Datalogger system.

Biology Usage

A plausible scenario for a human attempt to detect extant or fossil life on Mars is the use of a pressurized, three-person rover capable of exploration sorties of several days.

Such a vehicle could transport the crew to promising locations and provide support for specific EVAs. This is an inherently risky enterprise; astronaut-scientists leaving the rover to gather data and samples during EVAs are at greater risk than when they are in the rover. In this situation, a Datalogger is more than a tool for collecting information for further analysis. Because any astronaut might not survive, it is essential that all of the data be transmitted to the rover in real time to provide a permanent archive of the EVA. One way of looking at a Datalogger is as an enduser tool completely integrated into the entire mission information and communication system.

Datalogger Requirements for the Search for Martian Life. It is not known whether life exists on Mars now or at anytime in the past. We should make no assumptions about what biochemistry might have evolved on Mars, beyond the recognition that any life form must be able to extract energy from its environment. In this sense, biology exploration must be closely coordinated with geological study. Life on Mars, if it exists, is likely to be confined to protected environments which provide at least traces of water and shielding from UV radiation. An astronaut would need to search out such promising microenvironments, which might require maneuvering in difficult terrain. It would then be necessary to collect samples or take measurements, with commentary, to record details of the site. Samples would include soil and small rocks, and perhaps gases that might have been emitted as metabolic byproducts and prevented from diffusion by surrounding soil structures. These activities are only practical if the Datalogger is voice commanded, since the astronaut would need both hands to use tools and instruments. A digital camera, with zoom capability, should be integrated into the system to record an image of the site.

Datalogger Experience at MDRS – Biology EVAs. The following observation was received from a microbiologist regarding Datalogger usage during EVAs where biological samples were collected, and points towards a need for voice commanding of Datalogger functionality:

> I was involved in two EVAs during the Expedition One rotation where the prototype Datalogger was used, although on each occaision my crewmates carried the apparatus and entered the data and comments. I could not have reasonably done this myself, since I needed both hands to collect samples under sterile conditions. By recording comments and sample number, it was easy to identify the samples returned to the laboratory in their geological context. Attempting to use a keypad with gloves covered in dust invites failure of the mechanical system. Use of a field notebook would have been difficult and slow. Since an astronaut has a limited air supply, work must be done quickly, and writing is impractical.

Desired Datalogger Capabilities and Characteristics

Based on the geological and biological science needs and considerations outlined above, the following desired functional and operational capabilities and characteristics of a Datalogger for human Mars exploration EVAs can be proposed:

1. **Reliability.** As with all tools designed for long-duration human spaceflight, all aspects of the Datalogger system must be thoroughly reliable, simple, easy to use, and capable of being easily repaired or replaced. Experience over two seasons at MDRS has taught that equipment breakdown is a constant feature of field exploration. This is a very serious issue; how much time can a crew spend on equipment repair and calibration and still achieve their scientific objectives? Unlimited redundancy and spare parts is not an option, since they would need to be brought from Earth.

2. **Integration.** Ideally, the Datalogger hardware should be integrated into the EVA suit, at least partially. A heads-up display could be integrated into the helmet, or the display might be mounted on the lower sleeve. A removable CPU could be located elsewhere, such as in a backpack. An advantage of suit integration is protection from dust blown by wind or by disturbance from the astronauts' activities. The notion of integration also applies to the ability of the Datalogger system to interface with the wide spectrum of data collection devices that will be used by EVA astronaut-scientists, such as geiger counters, magnetic susceptibility meters, gas analyzers, PIMAs, etc. Full integration of the Datalogger system into the mission information and communications infrastructure also requires software and support for post-processing, analysis, and archival of the recorded data at the rover, habitat, and mission support level.

3. **Wireless data transfer.** Priority data, at a minimum (ideally all data if bandwidth allows), should be transmitted to the rover/hab in real-time for redundancy to protect against equipment failure. Multiple EVA astronauts could also share information via such a wireless data link. Wireless data transfer also provides the capability to remotely collect information from science instruments. Provision for separate data channels is required to allow astronauts to obtain data from multiple instruments simultaneously without interference. For example, a geologist could obtain readings from a PIMA, while a biologist would receive data from a thermal probe inserted into a small crevice, each without interference from the other.

4. **Voice commanding.** The use of reliable voice recognition software to activate Datalogger functionality is fundamental to allow full exploitation of Datalogger capabilities, given the challenges and workload that EVA astronauts must face. Reliable voice commanding leaves both hands free to perform other complex tasks, such as the collection of sterile biological samples.

5. **Voice translation.** Ideally, voice recognition software that could translate the verbal comments of the field scientist into text in real-time would allow quick reference to previous observations collected during an EVA and annotation, if needed. Current voice translation technology has not yet reached the level of accuracy required for this task (particularly considering the complex scientific vocabulary that would be used and sound distortion caused by the EVA helmet).

6. **Graphical display.** Obviously, a high-resolution color display would be necessary for a Datalogger system to be capable of displaying maps, photographs and other

digital imagery. With current technology, miniature graphical heads-up displays (HUDs) are available that can be integrated into a helmet.

7. **Image annotation.** The ability to annotate on-screen maps or photographs to highlight salient features is highly desirable, especially for geologists. Identification of the feature to be annotated could be accomplished via a touch-sensitive screen. Although this is almost impossible in normal gas-pressure space suit gloves, it is practical using mechanical counter pressure gloves[6] or using a specialized fingertip attachment. The ability to draw geological boundaries on images or make sketches would be a valuable way of collecting information that would be difficult to capture verbally.

8. **Redundancy for other systems.** A Datalogger could provide data storage, display and communication redundancy for other EVA systems, such as systems for EVA suit life support, monitoring astronaut physiology and voice communications. Suit indications or vital signs outside the normal range should cause the display of relevant warnings/alarms on the Datalogger display. While such an alarm would take priority over other display information, the Datalogger system should ensure that the contemporaneous scientific data stream is captured and stored.

ROLE OF INFORMATION USE IN PLANETARY EXPLORATION

Exploring Mars will require expertise beyond that provided by scientist-explorers. Sophisticated Dataloggers or wearable computers can employ technologies developed for current and future telematics and geomatics industries.

Telematics is the field of mobile information networking, allowing the remote access to vast archives of information and knowledge.[7] With the delay in communications between Earth and Mars, telematic solutions in handling documents, messages, moving and still images, sounds, spreadsheets and databases, will be needed to supplement the expertise of the exploring astronaut. Expert systems can provide the situational advice that ‘science backrooms’ have provided to astronauts exploring the Moon in the late 1960’s and early 1970’s. Science backrooms will never be obsolete, but much consideration and research should be carried out to understand how an astronaut team and a remote backroom might collaborate to accomplish the science objectives of a Martian expedition and to “perform science”. The potential use of telematics and expert systems to enhance that collaboration is a rich area for future study. Geomatics is the field of geographic information systems, focusing on the “collection, analysis, management and presentation of geographic information relating to land and property.[8]” To explore Mars, geological information will need to be acquired, archived and transmitted to Earth in its geographical context.

These two technologies will merge in future data logging devices. Mars-analog studies will need to confront the challenges of integrating this technology with the habits and practices of field scientists adapted to Mars. A robust Datalogger should not complicate the life of the geologist or biologist in the field, but enhance the ability to do useful science. Exploration strategies tested in Mars-analog investigations using

Dataloggers should focus on studying field science operations, performing task and work load analyses, and both scouting and site-specific operations.[9] These types of studies were included in the science program of Expedition One[3], and will in turn guide the development of the next generation of EVA Datalogger prototypes.

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