The NSBE Space SIG Tricorder Project

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Abstract - *Nothing is more iconic than the sight of Geordi from the science fiction TV series Star Trek: The Next Generation augmenting tricorders for use on planetary surface missions. Whether it was to determine the oxygen content, wind systems, or biological signs on the planet, the engineer of the Star Trek crew always played a vital role monitoring the environmental conditions around the crew as they discovered new planets and civilizations throughout the solar system. The NSBE Space Special Interest Group (SIG) channeled this when they took on their newest project of creating remote sensor handheld devices or the common environmental tricorder. The Space SIG is working on creating the environmental tricorders that captivated audiences for so many years and forever cemented the engineering genius of our favorite Star Trek characters. This paper reviews the current progress of the NSBE Tricorder project and describes options for future development.*

Keywords: Environmental sensor, tricorder, Mars Desert Research Station.

1 Introduction

This project is a result of the NSBE Space Special Interest Group's Space Leadership Retreat held in 2012 in Las Vegas. The team wanted to get more hands on research experience as well as prepare to utilize the Mars Desert Research Station (MDRS).

This paper will introduce MDRS, the NSBE Space SIG vision for MDRS and the objectives of the Tricorder project. It will provide the progress update from the 2013 Space Technology Session (STS-2013) meeting, and introduce the next generation Tricorders that the NSBE Space SIG intends to incorporate into future projects. It will finally give the Education component to the Tricorder project and show how the Tricorder projects will add value to NSBE across all membership demographics.

2 Mars Desert Research Station

The working environment for the tricorders would be the Mars Desert Research Station (MDRS) in the Utah desert run by The Mars Society. "In order to help develop key knowledge needed to prepare for human Mars exploration, and to inspire the public by making sensuous the vision of human exploration of Mars, the Mars Society has initiated the Mars Analog Research Station (MARS) project. A global program of Mars exploration operations research, the MARS project includes four Mars base-like habitats located in deserts in the Canadian Arctic, the American southwest, the Australian outback, and Iceland. In these Mars-like environments, we will launch a program of extensive long-duration geology and biology field exploration operations conducted in the same style and under many of the same constraints as they would on the Red Planet. By doing so, we will start the process of learning how to explore on Mars." [1]

Analog Research Stations are laboratories for learning how to live and work on another planet. Each is a prototype of a habitat that will land humans on Mars and serve as their main base for months of exploration in the harsh Martian environment. Such a habitat represents a key element in current human Mars mission planning. Each Station's centerpiece is a cylindrical habitat, "The Hab" an 8-meter diameter, two-deck structure mounted on landing struts. [1] Figure 1 below shows the inside of the Hab before an Extra Vehicular Activity (EVA).

Figure 1: MDRS Crew team before EVA

The NSBE Space SIG has sent four different students to the MDRS habitat "hab" in the Utah desert over the years as well as participated in multiple Mars Society projects and collaborations. Each simulation is a 2-week rotation with a 6-person crew, which includes a

Commander, Chief Engineer, Medical Personnel and Mission Specialist.

Figure 2: MDRS Crew member on EVA retrieving experiments

Part of these simulations involves EVA during which crews leave the habitat in full simulation to perform exploration, experiments and various Hab duties during their rotation.. Before the team goes to the habitat, the team comes together to determine the simulation rules for their rotations, what their experiments are and how each team member can support the other projects. Figure 2 shows two crewmembers collecting samples from an experiment for the biology lead team. MDRS provides a unique testing environment where the NSBE Space SIG can test projects, support research and fulfill their vision on how the NSBE Space SIG can grow in its vision.

3 NSBE Space Vision for MDRS

During the 2012 Space SIG Leadership Retreat, the Space SIG established the start of a space vision. This included a permanent NSBE presence at MDRS with yearly NSBE Professional and collegiate members participating on MDRS rotations. MDRS is in a perfect position to conduct public and educational outreach for NSBE Chapters and share the knowledge with the NSBE across the country.

The NSBE Professionals expressed the need for more hands on work and opportunities for publications and research. The field work advantage that MDRS provides is the perfect opportunity for NSBE professionals to explore technical qualifications, research, and ideas. Space SIG participants expressed a desire to get more hands on building experience. Tricorders where suggested from the open source design space called Open Tricorder project. A project grant was written and received from NSBE Headquarters during the summer 2012 which started the NSBE tricorder project.

4 Tricorder Objectives

The original NSBE tricorder objective was to provide hands on experience on how to build a sensor package from OED parts. Instead of starting from the blackboard, the team decided to start with the tricorder project designed by Dr. Peter Jensen. His information can be found at www.tricorderproject.com. [2]

The design is based upon an environmental sensor developed by Dr. Jensen and based on his Tricorder Mark 2 design. The layout design is given in Figure 3. The actual product produced by Dr. Jensen is shown in Figure 4. The crossover between Figure 3 and Figure 4 can easily be seen in the actual Tricorder layout.

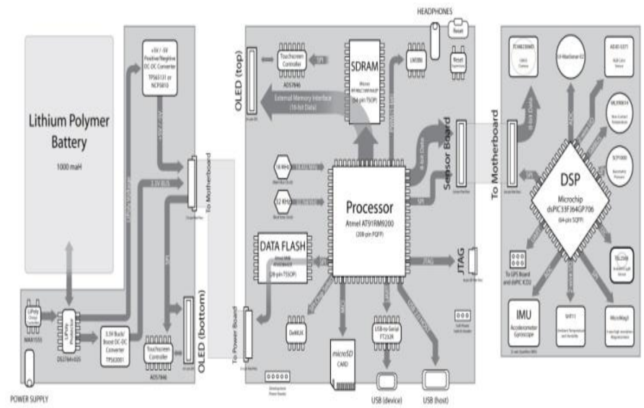

Figure 3: Tricorder Layout [2]

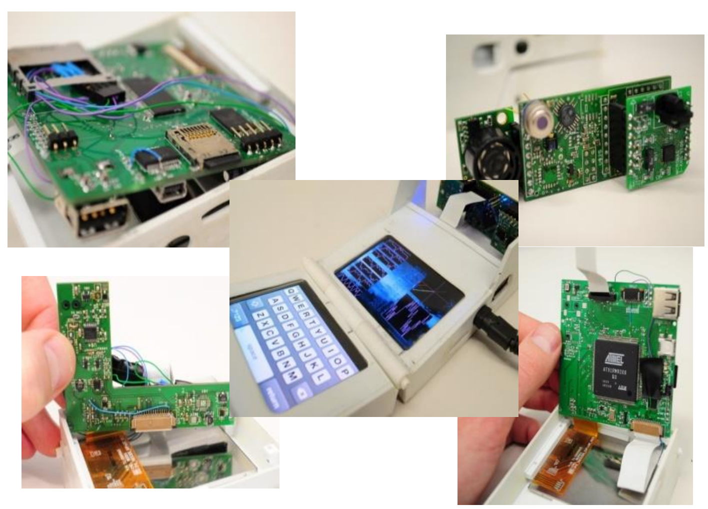

Figure 4: Tricorder [2]

The Mark 2 design utilizes 12 different sensors that when combined gives an environmental picture of the conditions for science experiments. These include electromagnetic, atmospheric and spatial sensors that when combined give a complete environmental picture that the Tricorder can be used for in the future. The sensors given in

Figures 5, 6, and 7 show three different sensor areas of Spatial, Atmospheric and Electromagnetic sensors. These fundamental properties are essential to a future science mission to categorize the environmental conditions of an experiment or situation that an astronaut may be presented. Using his basic design template, the team bought components from his master list and proceeded to put together the first generation NSBE Tricorder.

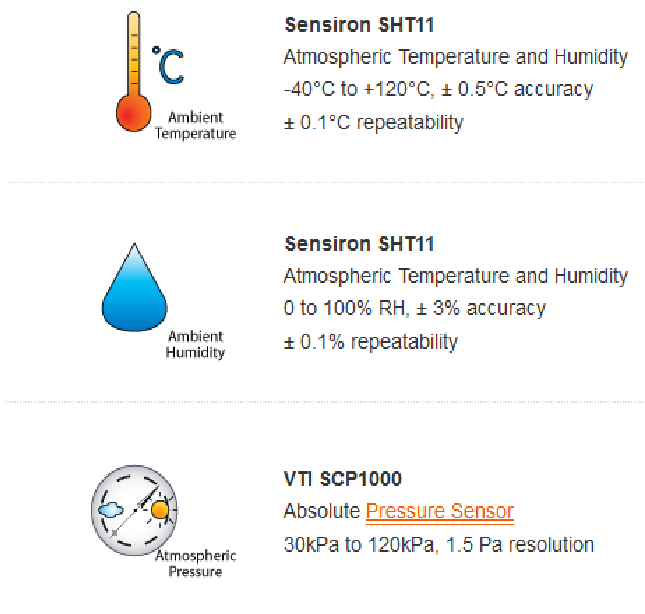

Figure 5. Three Atmospheric Sensors

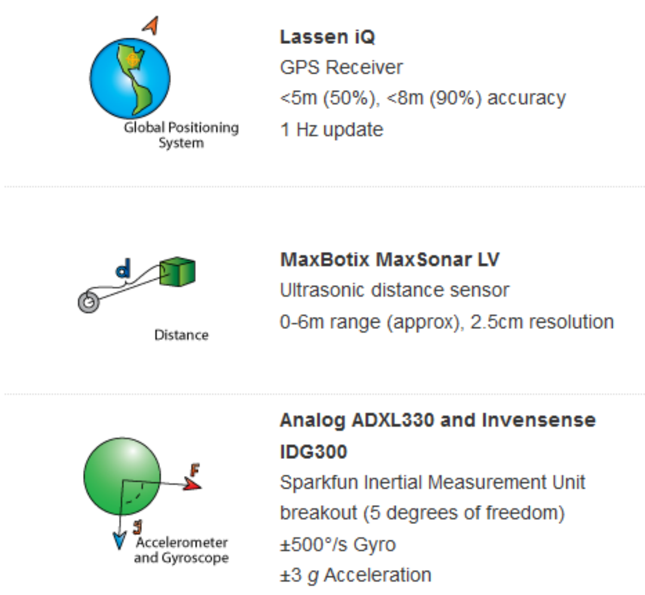

Figure 6.Three Spatial Sensors

Figure 7. Four Electromagnetic Sensors

5 STS-2013 Progress

During the STS-2013 working group meeting in Golden, Colorado, the tricorder team met to surmount obstacles standing in the way of the tricorder fabrication: Eagleworks fabrication software for Printed Circuit Board (PCB), pricing for PCB, and Organic Light-Emitting Diode (OLED) integration.

The Tricorder schematics were presented from the Tricorder Project. Dr. Jensen's original design provided Eagleworks files which are freeware files that present the circuit board selection from the basic schematic given in Figure 3 to actual PCB files for print out. The team determined how to create the right working PCB files to be sent and printed at a local company for fabrication of the tricorder at a later time. The team then priced out PCB's for a total of six Tricorder boards.

Finding OLED screens was more challenging then determining the PCB situation. When the Tricorder project was originally done in 2008, Dr. Jensen used OLED screens. These screens are light, flexible, and thin screens that can easily be integrated into the tricorder system. When the team went to order OLED screens, the only suppliers found were in China and not able to work with the NSBE Headquarters to supply the needed screens. The team therefore identified Thin Film Transistor (TFT) screens as well as tutorials on how to integrate the parts into the tricorder.

The team contacted the creator on this change, and he explained that he had the same problem since OLED screens had fallen out of wide use since he originally designed the first tricorders. The use of TFT screens changes the design to the original tricorder because they are a thicker screen. This change affects the thickness of the tricorder; it is perceived as a cosmetic change rather than a structural one. However, it is still a design challenge that the team must address.

The last task of the Tricorder team was to brainstorm new engineering and scientific sensors that the team would like to include in the design of the next generation NSBE tricorders. Section 6 presents results of the team's brainstorms as well as specific sensor integration for future tricorder projects.

6 Next Generation Tricorders

The team brainstormed multiple ideas for possible sensor integrations. Table 1 lists the possible sensors and engineering uses for a tricorder that the team brainstormed during the STS-2013. The team took these ideas as a first guess to look for the best ideas for sensors and possible integration ideas for the tricorder project. The team divided the possibilities into actual hardware sensors that could be incorporated into the tricorder vs. a software package that could utilize the sensors that were already included in the environmental package.

Table 1: Brainstormed ideas for next generation tricorders

Brainstormed ideas	
Wifi Protocol or Bluetooth	Scanning for Material Integrity
Software Utilization	Mapping Software
Identify Organic Compounds	Spectrometer
Sonar Sensor	Gas Detection
Multimeter	Signal ID
Solar Powered	Magnification (optical)
Video	
Personalized sensors	Manufacturing Tolerances

Working from these possibilities, the team determined that the Wi-Fi Protocol, Solar Power, and Gas Sensor/Spectrometer were the best sensors to investigate during this time for a possible next generation tricorder. A fourth project called the HiJack component was investigated and suggested as a future project. This section will go through each of the four possibilities determined as the best solution for the current tricorder. Section 7 will go through the education component of the Tricorder which incorporates some of the other ideas brainstormed for the education component.

6.1 Wi-Fi Capability

Adding a Wi-Fi capability would allow the tricorder to directly coordinate with the on-line community, receive updated software, and upload data information to the Internet for receipt on the mission control end. Accessing the Wi-Fi network at the Habitat is easily done for upgrades during the 2-week rotation. Figure 8 shows the components involved with adding a Wi-Fi capability. A Wi-Fi USB dongle microprocessor would be dismantled and hardwired to the available space of about 1" X 0.25". The Wi-Fi antenna will be glued with two part epoxy on the other mainboard enclosure (~ 3 inches) as indicated in Figure 8.

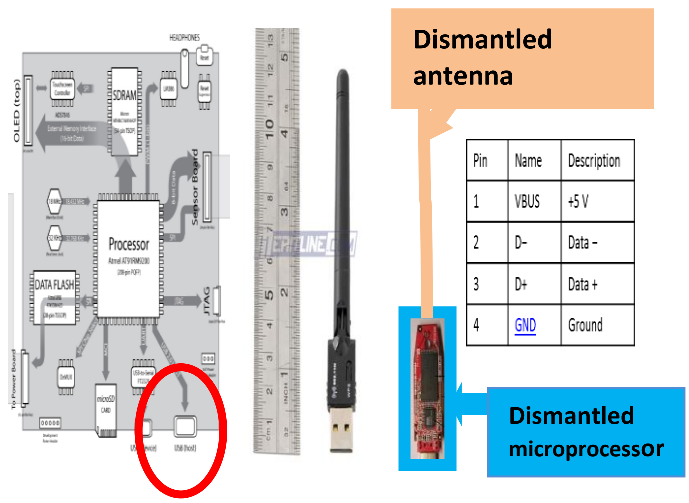

Figure 8: Wi-Fi component Breakdown

The USB dongle will be integrated with the existing AT91RM9200 microcontroller configured for Ethernet 10/100 Base-T Media Access Controller (MAC) which provides telecommunications access. The average vendor cost less than $15.00. This assembly and integration example for a Wi-Fi component shows a preliminary system that could be integrated into the schematics given. The next aspect would be to program the microprocessor to take advantage of the Wi-Fi capability.

6.2 Solar Power

The current power system is a rechargeable lithium ion battery. In order to ensure battery energy is conserved and the Tricorder device can be used in emergency situations a solar power source was suggested. It allows the security of having a backup energy source; however, it also adds bulkiness to the Tricorder that may affect the ability of the Tricorder to fold as planned. The smallest solar cell found had specifications given in Table 2 and shown in Figure 9.

Figure 9: Sparkfun Solar Cell[3]

Size	3.7” x 2.4”,
Energy	0.45W
Voltage	4.95V
Current	100mA

Table 2: Solar Cell Specifications

The average efficiently of a solar cell is 15%. Ideally the tricorder could integrate two solar cells onto the outside of the casing to get twice the power back up to the lithium batteries. The cost is less than $15 per cell. [3]

6.3 Gas Sensor/Spectrometer

The team brainstormed a gas sensor/spectrometer for substance and atmospheric identification purposes. The largest challenge with incorporating a spectrometer is finding a sensor that is small enough to be integrated into the tricorder form factor. The team identified the Qstick spectrometer that could give field measurements, chemical analysis, solar measurements, environmental analysis, and colorimetry options. These applications are fundamental environmental conditions that could affect EVA experiments. The Qstick spectrometer is shown in Figure 10 with the specifications given in Table 3. [4]

Figure 10: Qstick spectrometer [4]

Table 3: Qstick specifications

	Specifications
Wavelength range	360 - 740 nm
Entrance slit	30 µm
Spectral resolution	< 1.0 nm
Dynamic range	> 300 : 1 (full scale, texp = 1 s)
Stray light	0.5 %
Numerical aperature	0.07
Exposure time range	5 ms to 30 s
Detector	2500 pixel linear CCD detector
Calibration	Wavelength, sensitivity and multiple dark spectra stored within device
Transfer speed to PC	200 ms per spectrum
Optical interface	SMA connector
Digital Interface	USB 2.0
Dimensions	85.7 × 22.0 × 10.0 mm (technical drawing available on our website)
Weight	25.0 g
Operating temperature	-15 °C to 60 °C (non-condensing)
Storage temperature	-25 °C to 70 °C
Power consumption	5 V DC, 150 mA (supplied via USB, no power adapter required)
PC operating system	Windows 7, Vista, XP

6.4 HiJack Component

The HiJack component is a communication protocol that utilizes the 3.5mm headset jack found on most smart phones. It was pioneered at the University of Michigan. The tricorder has a 3.5 mm headset although the team originally ordered a 2.5 mm headset. The HiJack protocols has been used as a platform to connect a variety of sensors from temperature to being used as a 2-lead EKG.

The HiJack component provides an excellent education tool that students can use with their smart phones during the school year to determine how a sensor system works and then program the same hijack device to work on the NSBE tricorder at the Hab. The hijack device allows for students to design sensors, conduct experiments, and subsequently connect their experiments to the NSBE Tricorder for a “field test”.

The HiJack components are relatively inexpensive and readily available to build the HiJack modules. The University of Michigan has released the HiJack software application into the public domain, and is free for download in iTunes and Google Play. In order for the Tricorder to accept HiJack modules, the audio subsystem would need to be modified to accommodate a microphone channel. [5] Examples of the HiJack device are shown in Figure and Figure below.

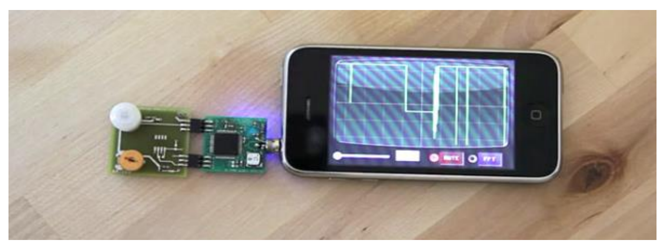

Figure 11: HiJack device [6]

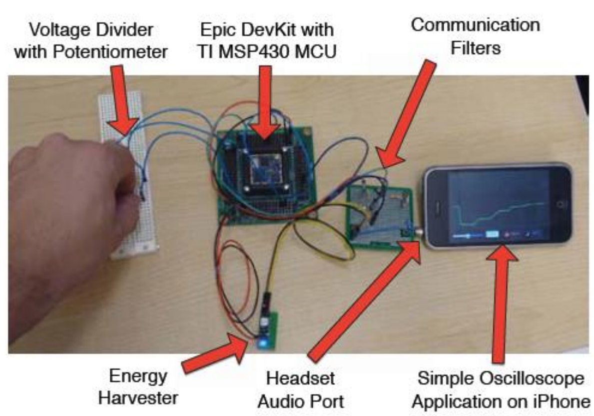

Figure 12: HiJack Device [6]

All of the original sensors as well as the add-on NSBE sensors are part of an overall education plan that would allow for NSBE and NSBE Jr. Chapters to participate in the NSBE Professional expeditions to the Mars Habitat in Utah.

7 Education Component

Ultimately, NSBE Space SIG seeks to establish a regular NSBE presence at the MDRS in Utah. NSBE Space will conduct an initial MDRS expedition perhaps as early as 2015. Each crew member must have a science/engineering project or experiment. Two experiments for NSBE expedition crew involve the tricorder. One will be used to accompany EVAs to measure environmental conditions in support of other experiments. Previous MDRS crew experiments included projects that involved burying slides to see if cells would grow on them after two weeks and experiments conducting rock curing for geology experiments to determine the rock conditions and weathering systems. Both are examples of experiments that could use the tricorder to record the environmental conditions of the samples and correlate the results to the weather conditions that day. The extended tricorder could eventually use the spectrometer to identify the rock samples before bringing them back to the Hab, as well as the rock specimens to check for growing cells for life.

The second experiment is to build a tricorder at the habitat. The team purchased enough parts for 6 tricorders. A possible experiment for a MDRS expedition is to perform an in-situ test to assemble a tricorder. This could be organized in conjunction with an assessment of a habitat maintenance workstation.

Coupling sensors (using the multiple sensors contained in the tricorder) to determine various characteristics leads to an educational component of the Tricorder Project which would be a software tricorder challenge. The software challenges would challenge NSBE Chapters to create interfaces and interpret data from coupled sensors. The idea would be to have NSBE Hacker Challenges and perhaps a Hacker day for the computer science community to engage in the environmental side of the NSBE Tricorder project.

8 Conclusions

The current NSBE Tricorder project is being pursued to understand how to develop a tricorder in order to incorporate a tricorder prototype into scientific operations on a NSBE MDRS expedition. Building the tricorder and using it at the MRDS provides hands-on experience for the NSBE Professional. A proposed timeline is given in Table 4 to lead up to the first NSBE MDRS expedition.

Table 4: Tricorder Ideal Timeline

Calendar Year/ Quarter	***Milestone***	***Task***
Y14Q1	ASC2014	Tricorder Demonstration New sensor integration
Y14Q2	Space SIG Leadership Retreat	NSBE Hacker Challenges Issued
Y14Q3		Expedition Crew Call for 2015
Y14Q4	NSBE FRCs, PDC	Tricorder Demonstration
Y15Q1	STS-2015	Crew Working Meeting

Acknowledgment

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