The Data Acquisition and Storage System (DASS)

Project Proposal

Design Group 12
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We pledge our Honor that we have abided by the Stevens Honor System.

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I. Abstract.

This project proposes to build a device which will greatly increase the efficiency of data collection in the oceanographic community. Currently, there exists a very popular product made by the Campbell Scientific Corporation which is used to interface with a variety of instruments and retrieve data. This device is unfortunately difficult to work with, with a very small amount of memory and only a slow serial port connection for data transfer. The group proposes to build a device to enhance the connectivity of the Campbell product by incorporating Ethernet and USB ports and providing a factor of 65 increase in onboard storage over standard. The design will incorporate a relatively inexpensive and common single-board computer to interface with the Campbell device and accomplish these important improvements. These new features will significantly increase the amount of time the datalogger can remain in the field unattended and significantly decrease the amount of time needed to download data from it. Given the usually remote location of data collection this is a significant advance. At the conclusion of the product the group intends to have a functioning prototype working with at least one Campbell device.

II. Project Proposal Plan

1: Introduction.

Campbell Scientific has provided a wide variety of additions to their data loggers that allow for additional memory, Ethernet connectivity, and radio communication. Unfortunately, while these additional components fit into Campbell Scientific cases and are designed to work with their products, they are very costly and cannot all be included in one device. Campbell has not yet provided a method for increased data download rates from their loggers. According to the team's research, there has been no effort outside of Campbell to provide these kinds of enhancements to their data loggers.   The current limit of enhancement has been to directly connect the Campbell device to a PC in order to increase data storage space and accomplish a quasi real-time based systems for displaying data. While done by some groups for laboratory-only applications, this is obviously not practicable for field work, and is not cost effective.

This is where the Data Acquisition and Storage System represents a marked advance. DASS will provide the hardware to upgrade a Campbell Scientific CR-10X with Ethernet connectivity, additional storage space, fast data manipulation capabilities, and fast data download rates through USB 2.0 protocol. The key aspect of this project that will allow it to surpass the various Campbell components will be the affordability, integration, and improved speeds of all of the Campbell provided services within a single device.

The Campbell Scientific CR-10X currently connects to a PC through an RS-232 connector, which provides a maximum data download rate of 9600 kbps. Unfortunately most laptops are no longer equipped with RS-232 ports. Since laptops are generally used for data collection due to the ease with which they can be deployed in the field, this creates an inconvenience for any scientist or engineer working with the CR-10X or other Campbell Scientific data loggers. Although USB to RS-232 connectors do exist, it is inconvenient to have to carry them to the device and might lead to wasted trips in their absence. Most importantly, these connectors cannot provide USB data rates, but only RS-232 rates through a USB port. The DASS will be providing USB 2.0 data rates of 480 Mbps, a factor-of-48 speed increase. This change in connection will certainly reduce time spent downloading at the usually inconvenient and frequently uncomfortable locations at which data is generally collected.

The DASS will also provide a large increase in on-board data storage space. The CR-10X comes with a maximum of 16 MB of data storage space on board. This will be surpassed by the DASS's potential for 1 GB or more of data storage space. This factor-of-65 increase in data storage space will allow the DASS to hold more data and will allow the Campbell to remain in use for much longer periods of time without being physically accessed.

Ethernet connectivity for the DASS will allow for remote data collection when deployed in Internet-accessible areas. It will also greatly speed up in-laboratory testing and experimentation. Additionally, warnings regarding power concerns or data storage concerns will be able to be sent out via email to keep the owner of the device up to date regarding how it is handling its environment and mission. Potential for nearly real time data retrieval remotely will also become a realization, allowing for quick analysis and display of data.

Campbell Scientific Feature	Capability	Cost	DASS Feature*	Capability
RS-232 Connection (S)	9600 kbps	Included	USB 2.0 Connection	480 Mbps
Ethernet Connection (A)	10	$395.00	Ethernet Connection	10/100
RS-232 to USB Adapter (A)	1 Mbps, 9.8 ft	$40.00	USB 2.0 Connection	480 Mbps, 16 ft
Flash Storage Memory (S)	16 MB	Included/ $600 to upgrade	Flash USB Stick	1 GB
Compact Flash Memory Unit (A)	1 GB	$540.00	Flash USB Stick	1 GB

(S)=Standard Feature
(A)=Add-on Feature
*All DASS features will be standard, at no additional cost for the unit

Table 1: Campbell Scientific Features vs. DASS[1]

2: Design Requirements.

Consultation with the members of the Davidson Labs staff (who will be the initial end-users of this product) revealed a degree of flexibility in the necessary specifications. In short, the current Campbell product is primitive enough that any sort of improvements to data transfer rates/storage sizes would be a significant achievement.

The following list contains the critical aspects of the DASS design.

1) The device will periodically store data to the external flash memory, ideally every quarter to half an hour. The period cannot be so short as to run up against read/write cycle limits of the flash memory, nor so long as to have significant amounts of data loss in case of unit failure.
2) The device will communicate with the Campbell device in standard RS-232 format at a rate of 9600 kbps with an 8 stop and one start bit format[2]. It will be designed to both receive data and transmit commands.
3) Device commands will be in format of ASCII strings.
4) On power-up, the sbc will automatically boot up and communicate with the Campbell logger if connected. This boot sequence will indicate any malfunction on the device's part.
5) Data will be retrieved from the Campbell logger and formatted into packets. Currently, there is a significant amount of "garbage" in the received data and it is wasteful to store and download this.
6) The device will send these packets through the Ethernet port either automatically or on-command.
7) The device will detect imminent power failure and shut down safely to prevent disk corruption. It will also save any data from the RAM to flash memory before quitting.
8) If connected via Ethernet device will automatically send out a system malfunction and/or power-failure signal via email.
9) The device will use a LINUX software environment and will be programmed in the C language.
10) The device will need a minimum of 32 MB RAM, 512 MB external flash memory, one USB 2.0 port, one serial port, a processor speed of 200 MHz, and a power supply consuming less than 4 watts.

3: Design Approaches.

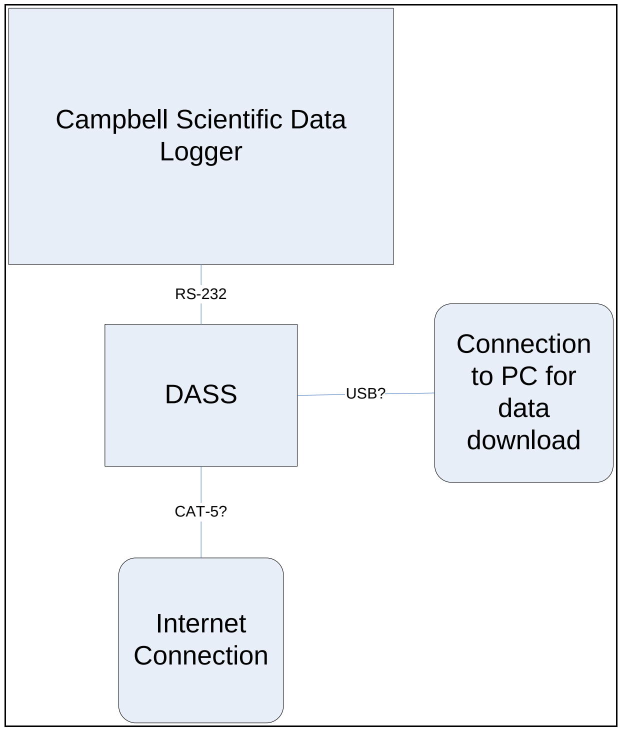

Figure 1: Conceptual Layout of the DASS and Campbell Logger

Hardware

The CR10X data logger itself performs many functions which serve the data collection needs of the scientists who use them. The expansion, which the group plans to design and build, comes with several requirements which have been specified by the scientists at Davidson Labs. These specifications play a major role in determining the type, size, and features of the SBC (or Single Board Computer) which the group plans to utilize. Peripherals, such as a backup battery, a solar charger, flash memory, and possibly a wireless Ethernet connection are also in the scheme of the original design ideas. With the specifications and cost in mind, the group laid out its plans for the possible designs.

The group's first task is to find an SBC that has several types of connectors available for use. The different connectors include multiple USB ports, a serial connector, a flash drive, and an Ethernet port. The decision to utilize these methods of connection and storage comes from the needs of the scientists at Davidson Laboratories Research Facility. The first SBC found through initial research seemed most promising. This specific SBC is the TS-7200 from Technologic Systems[3]. This particular device provides the multiple ports and connections the group is looking for. Finding other SBC's with similar features is proving complicated. At one point, a similar SBC was thought to be found until the group quickly realized that it have too many serial ports and not enough USB ports, and research into this other board was dropped. The potential to use a minicomputer system such as that provided by a MicroITX is also under consideration.

This would provide a system similar to an SBC, but as an enclosed and full computer system that is not intended for embedded amplications. This brings up a concern with power consumption

Choosing the SBC that will be used requires making sure that all of the components which the group plans to attach to it will work with the peripherals that are specified. Being able to collect, package, and send data simultaneously is quite a task for a computer, so the actual data rates that will be sent from the data logger itself will have to be collected efficiently by the SBC. In order to verify that the board the group chooses will work to specifications, an actual testing of the data transfer rates and collection capabilities from just the computer to the expansion will be run with small sets of data at first. A few larger files will be sent after verification of the continuity of the data sent in the smaller files. At this point of development, the actual operation of the datalogger when connected to the expansion is unknown, so testing of the SBC will also include verifying that the expansion can, in fact, collect, store and send small files in initial testing.

The group believes that most, if not all peripherals for this board will be mostly “plug-and-play”, but only testing will prove whether or not this is true. In the original design of the expansion unit, the group thought the data logger would be sending an analog signal carrying data, which would then require a digital conversion somewhere on the SBC that the group chose. This particular A/D conversion posed a problem for the group. Because the conversion would require a close look into how to program this into the SBC as well as finding the right parts to do so, the group needed to make sure that the SBC itself could handle the conversion without taking up too much of the operating power. To have one function using up a lot of operating time and power would be taking from all of the other functions which would be occurring simultaneously. The group then decided to consult the scientists again and found out how the data was going to be transmitted from the data logger to the expansion. After a quick consultation, the group was relieved to find that the data would not need converting. Knowing this, the software design later could prove to be much easier than expected.

Other peripherals, such as a back-up battery and a solar charger are devices that may not be as easy to test as the data through the SBC. Solar panels are expensive and can take up a lot of space out in the field. The small solar panels that can be bought commercially may not provide enough power no matter how much sunlight the panels get. Even though the actual power generation of the solar panels may not be large enough to operate the SBC, the use of solar power may aid in powering the data logger expansion, should the constant power supply stop working. The actual output of the solar panels can be put to the test by placing the panels in an open field or even under a powerful lamp to test how it responds. Concerns will remain about how effective the panels will be in order to be considered a viable power supply.

In order to supplement the solar power and the power grid a battery suppl y will also be included. The SBC itself requires at least 5V to operate properly and, according to Davidson Laboratoriess staff, will have to provide enough power to keep the data for up to 5 days, should the main power supply fail. The issue here is the type of battery to use for this type of application. Since the team is not yet familiar with the actual power consumption of the SBC with all of the peripherals connected to it further research will be required in order to choose a battery with the ability to maintain a functioning system for up to 5 days. Most commonly used for rechargeable batteries is the Ni-MH battery which charges slowly, is low in cost, is easily replaceable, and could potentially run for the specified amount of time. However, a Li-Ion battery is safer to use than the Ni-MH battery and can possibly provide power efficiently to each of the devices so that the charge lasts for as long as necessary. The only issue with the Li-Ion battery is that it tends to cost several times more than a Ni-MH battery and can therefore become an issue if a battery fails. Also, the temperature of the battery within the data loggers casing can become an issue. Batteries perform differently in different temperatures and extreme temperatures can potentially shorten the life of the battery. The group will try charging the batteries with the solar panels and see how they will operate over time. One thing the group is keeping in mind is that these batteries are meant to be used solely as back-ups and not as constantly used power sources; there is a main power source for standard operation. Ideally, the batteries will be kept charged with the solar panels, so that the power will not fail and could perhaps last the 5 days that is specified. The only way to possibly test this is to see how long it takes to charge the batteries and whether or not the batteries are more efficient if they are simply replaced instead of constantly recharging batteries being used.

200 MHz ARM 9 processor with MMU for Linux.
2 standard serial ports with 16 Byte FIFOs
Watchdog timer unit
32 MB of High Speed SDRAM
8 MB (16 MB opt.) Flash disk used for RedBoot boot-loader, Linux kernel and root file system
Compact Flash Card interface
10/100 Ethernet interface - autosense, LED indicators
2 USB host ports
20 DIO lines
PC/104 8/16 bit bus
SPI bus header
Rugged quick-release terminal strips used for power
Dimensions are 3.8 " x 4.5 " (PC/104 mounting holes)
Power requirements are 5V DC @ 400mA
Operating Temperature Range: **Fanless** 0°C to 70° C
Optional Extended Temperature Range
Optional Battery Backed Real Time Clock
Optional **RS-485** support on COM2 with fully automatic TX enable control
Optional 8 ch. 12-bit A/D converter
Optional on-board temperature sensor

Table 2: A Summary of the Features of the Technologic Systems TS-7250

Software Design

Choosing an SBC not only for its hardware capabilities, but also for its operating platform is an important issue for the group. One SBC that the group found SBC is programmable through Linux. By being able to run the software in Linux for this expansion unit, the team actually using the device will have an easier time programming and eventually adapting the system to different conditions. Also, since the group prefers to program in C, the operating system should not be complicated and should be non-proprietary. The choice to program in C comes from the fact that most embedded programming is in C, and conforming to such a standard is an excellent way to make a product more accessible and easily modified for future development. C is also a programming language that all group members have some experience with, which will allow all of the team to get up to speed on the programming portion of the project very quickly.

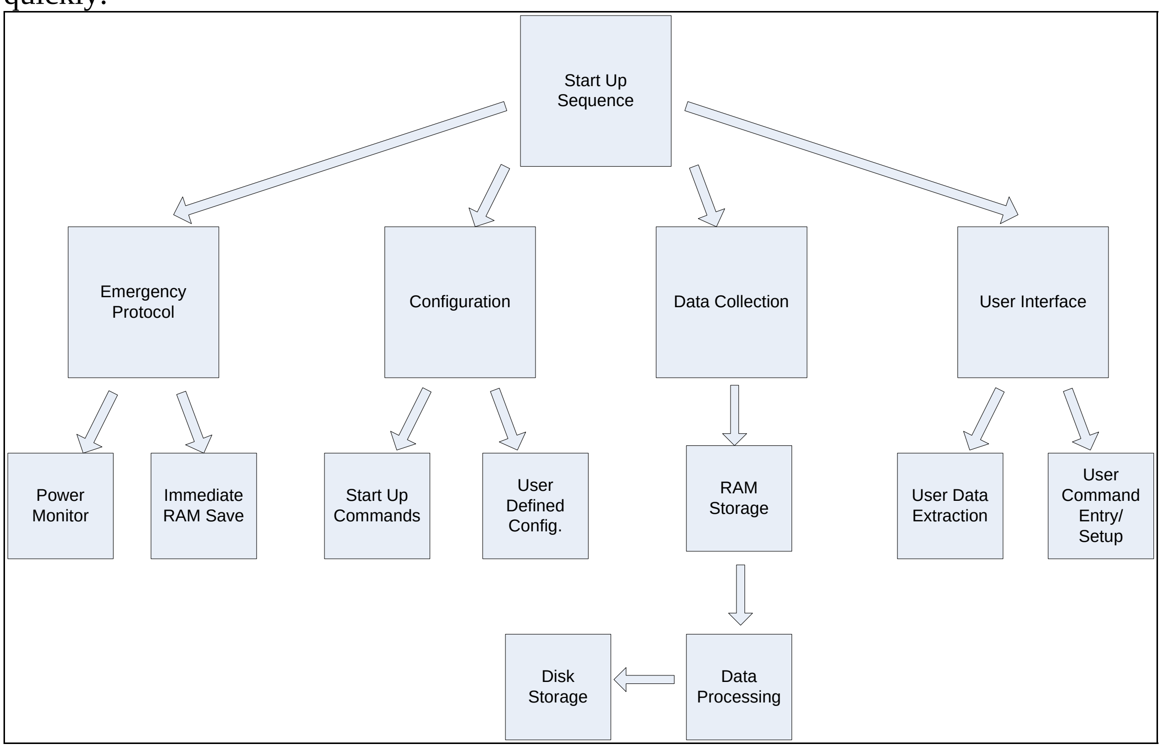

Figure 2: Conceptual Layout of DASS and Campbell Logger

With regards to the design of the software, an important issue will be the use of the serial port. Since a serial port can only be accessed by one piece of software at a time, serial port handling will be an important priority. The options regarding handling the serial ports include creating a specific script for controlling the serial port, or designing an interwoven hierarchy between the various programming scripts that enforces a set of handling rules. One advantage of a specific handling script is a centralized control of the serial port. A centralized control of the serial port also implies that errors regarding handling can only come from one part of the code, which will make troubleshooting during development a lot easier. The advantage behind an interwoven system to handle serial ports lies in the potential to have fewer scripts running on the system as well as ensuring that certain scripts have priority over others.

Another important decision that the group will need to explore further is what scripts will need to be running for this system to function properly. The DASS needs to be able to collect data, process data, store the data to disk, protect against power loss in emergency situations, handle Ethernet connections and communications, and be able to interact with a user through USB all at once. Perhaps not all of these functions will be running simultaneously. The group will therefore have to decide whether all functions should be running simultaneously, or if there should be a central script that controls what functions are running at any given time based on certain operating factors that are to be determined. This will be an important situation, especially with regards to keeping the DASS's processor running efficiently and keeping memory clear for data manipulations.

4: Financial Budget.

Obviously, certain budget elements will be missing from this project that would be crucial to any other, particularly those of profit and wages. Expenditures will largely be for parts necessary to build the device.

The most expensive device is the SBC itself. The group intends on purchasing a minimum of two to make them more readily available for work outside the laboratory.

Embedded x86 systems model TS-7250 SBC	$119.00	2	$238.00

Table 3: Cost for SBCs[4]

Various options will be considered for the battery charger. Perusing the Digi-Key catalog gave us several examples in the four-dollar range for single-unit quantities. Obviously the group will try to obtain samples if possible. Considering design changes and bad chips, estimated cost here is $50.

Solar panels are another issue. The most promising at this moment is actually a commercially-available car battery tender priced at $29. It will provide two watts at twelve volts, which is sufficient. Different kinds of solar cells are avialble, at different prices: the more power per unit area, the greater the cost. Estimated cost for elements of the solar array is $100.

Flash memory will be necessary, either in the form of a CompactFlash card or a USB stick. At current rates, 1 GB will cost about $100[5].

An enclosure will be necessary, preferably aluminum. One particular model seems desirable and costs $8.93 in single-unit quantities.

Shop supplies (solder, flux, etc.), connecting wire, resistors, capacitors and the like will probably not run more than a total of $75 over the course of the project, and considerably less if scrounged.

Other expenses:

Space is not an issue, at least in terms of cost. Work will be done in one of the laboratories or at the residences of the various group members.

Printing up documents is also not expected to be significant, as the group has access to the plotter and each have printers at home. Two reams of printer paper for a total of $10 will suffice. A package of rewritable computer disks should also be factored in at $10.

The software the group plans on using is open-source, so there are no licensing fees to consider. Additionally, the group has Microsoft Office already installed on their machines.

Little travel is anticipated. Davidson Laboratories is on campus and all parts are expected by mail order.

Phone costs are also not a great problem, particularly in the age of cellular phones with pre-determined numbers of minutes of talk-time. $30 should cover most of the talking imaginable over the course of the next two semesters, especially considering that the group prefers the instant-messaging medium

The team has or expects to have access to one Campbell machine, so the cost of this is not anticipated. If this access were to be lost the expense would be more time-based, as a software simulation of the product would be necessary.

Specialized test equipment would be limited to digital multi-meters, a scope, and several older computers running LINUX to test software at home. All of these are currently available to members of the group outside those available in the laboratories.

Total cost of the project, including sales taxes, is estimated at $675.

III: Conclusion.

It is apparent from the group's preliminary research that this project can be realized in the course of two academic semesters. The intent of the project is to develop a prototype and conduct a limited amount of field testing by the conclusion of the spring semester. If additional time is available the incorporation of a wireless or radio link can be accomplished: if not, the work of future persons and semesters can be devoted in this vein. The cost is reasonable, especially in comparison to the procurement of one stock device with some of these features, and sponsorship has already been obtained from Davidson Laboratories. The principal amount of time will be devoted to developing software for the SBC. As a result, given the development of a prototype, limited-scale production for Davidson Laboratories' use can be immediately established. Though this is no small amount of work, with proper time management it is achievable. The project is useful in that it will result in an immediately useful tool which will be of great use to the client.

IV. References

[1] Campbell Scientific. "2005 U.S. Price List."
[2] Campbell Scientific. *CR10X Measurement and Control Module Operator's Manual.* 1986. Campbell Scientific Inc.
[3] Technologic Systems. Available on WWW: http://www.embeddedx86.com/Manuals/TS-7200_Rev1.4.htm
[4] TS-7250 Price and Feature Guide. Available on WWW: http://www.embeddedx86.com/epc/ts7200-spec-h.html
[5] Best Buy Website. Available on WWW: http://www.bestbuy.com/site/olspage.jsp?skuId=7393643&type=product&productCategoryId=cat01049&id=1122655258596