Woods Hole Success Story

Utilizing Agilent VEE as part of a Data Collection Program for Surface and Undersea Research Vessels

Configuring a highly-versatile application that would fulfill the demands of the scientists on board was challenging, indeed.

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Figure 1.

The 279-foot *R/V Knorr* has a range of 12,000 nautical miles and can accommodate 32 scientists and 2 technicians. It is one the Woods Hole Oceanographic Institution's surface vessels equipped with the *Athena* data logging program.

"Underway" oceanographic instrumentation might not be recognizable as test and measurement to many of those working in other T&M sectors. An oceanographic data logging system must deal with measurements related to the ocean, the atmosphere, and the measurement platform itself — sea temperature and conductivity, barometric pressure, ship's heading, pitch, roll, and the like. This means collecting slowly-changing information — and the measurements seem to go on forever.

One of the principal missions of the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts and its research vessels, such as the *R/V Knorr*, shown in **Figure 1**, is to collect, record and process data at sea. Any data logging program that is devised must meet the diverse requirements of the researchers utilizing the ships for cruises lasting up to a month. At the same time the program must be sufficiently flexible and easy to use to allow technicians on board, with little specialized programming experience, to quickly make the changes necessary to meet the diverse requirements of newly arriving scientists.

This article begins by describing earlier DOS-based programs that we employed – and their shortcomings. These gave us a base to develop a clear set of requirements for a program that would truly meet our needs. We then move on to Agilent VEE and why it became the basis for the program we ultimately developed.

First let's take a brief tour of oceanographic research.

Data Logging and its Role in Oceanography

Oceanographic research remained in the dark ages for many years in respect to shipboard data collection. This stemmed, in part, from the fact that when a research vessel was at sea, it was quite difficult to determine its precise location. To be sure scientists with cruises aboard Woods Hole vessels were able to acquire incredibly detailed and accurate data along the vertical axis, but in the horizontal plane of the ocean surface, they could never be quite sure where they were. (See below, *"How Woods Hole Assists Researchers."*) But once the global positioning system (GPS) brought accurate and continuous navigational data to our vessels, oceanographers were finally able to marry their vertical profiles with their position in the horizontal plane.

Early Oceanographic Data Logging Equipment

Initial efforts to add standard instrumentation to our ships resulted in a hodge-podge of computer systems with a mixture of programs written for use under DOS. Just about every instrument had its own batch file or vendor supplied control program. As a first attempt to improve this situation, the SAIL system was invented and deployed on our vessels. This was a hardware and software "standard" that allowed many instruments to be connected via a serial data current loop and therefore controlled by a single computer program. This helped considerably by providing a degree of organization to a sub-set of a ship's instrumentation but there remained many loose ends, which caused problems as the researcher's requirements and expectations increased.

How Woods Hole's Marine Operations Assists Researchers

The Woods Hole Oceanographic Institution based in Woods Hole, Massachusetts on the southwestern tip of Cape Cod, provides services for researchers that use its marine equipment. The equipment is primarily the surface research vessels, such as *Oceanus, Knorr, Atlantis* and *Asterias,* but it also includes a group of vessels designed for deep-sea exploration — such as the submersible *Alvin,* cable controlled vehicle *Jason II*, and autonomous robots such as *ABE* and *Remus. Alvin* can carry a pilot and two scientists to depths of 4,500 meters (14,764 feet). The research vessel *Atlantis*, which is the mothership for the submersible *Alvin*, is shown in **Figure 2**. *Alvin* is shown in **Figure 3** and is carried routinely on the *Atlantis. Alvin* is currently this nation's deepest diving submersible and is possibly best known for its role in studying the sunken passenger liner Titanic.

With regard to data collection and logging, the *Alvin* submersible behaves very much like other research vessels and has the same challenges.

In the early days Woods Hole supported scientists by providing them with what were virtually 'barebone ships' — with regard to instrumentation. If you were a researcher interested in collecting data at sea, you could utilize one of the research vessels, but you would be expected to bring just about all the instrumentation you would need. We would help you do whatever you wanted, but we wouldn't provide much in the way of research equipment.

As time went on — and particularly as navigation capabilities improved — it became important for each research vessel to be equipped with a suite of standard instrumentation. Researchers came to expect such a suite on all research vessels – with GPS navigation being just one of the vital instruments. A number of other instruments, sea-surface sensors for instance, had been important in the past — but not critically important because without accurate, continuously recorded navigational information, you never knew exactly where you were, which greatly decreased the value of each sample.

Modern oceanographic research ships, utilizing state-of-the-art navigational instrumentation, know where they are to within a few meters, so the information collected by the ship's "underway" sensor suites has become vitally important — which is why we developed the *Athena Data Collection, Logging, Display and Distribution System.*

Figure 2 (Above). The 274-foot Atlantis Research Vessel built in 1997 is specifically equipped to support the submersible Alvin.

Figure 3 (Below). The 23-foot Alvin submersible, with two scientists and a pilot on board, typically conducts 10 hour dives.

In order to provide a higher level of organization to the chaos, we wrote a unified data collection, logging, distribution, and display program using a fourth-generation, database programming language. This program worked well for many years, allowing us to remain ahead of researcher demands while providing valuable experience for the future. Unfortunately, technology marches on and our DOS based programming masterpiece became obsolete when Windows grained acceptance. As a result, we were forced to begin the long process of developing a suitable replacement and the first step was to identify the real needs as opposed to the gold plating.

As a benefit of having worked with the early data collection software we were able to generate a realistic set of requirements for the new program. Here are three of the higher level concerns that we considered to be the most critical:

- **Flexible –** The program would be required to operate differently for different cruises and different vessels.
- **Manageable –** Technicians would need to maintain, configure and operate the program with limited programming knowledge.
- **Supportable –** Configuration documentation must be easily generated and transferred between support personnel on shore and at sea.

The Search for a Program

We knew from experience that despite our best efforts, we would not be able to generate a program meeting everyone's needs without the requirement for some amount of programming in the field. The goal was to limit this to "add-ons" that could be written or adjusted by the technicians and then used by the primary program without modification. Never-the-less, it was considered important for the technicians to have an understanding of how the primary code functioned and an appreciation for its strengths and weaknesses. This was a strong consideration when selecting the primary programming language. Almost immediately we rejected some of the high-powered languages that would normally come to mind because, though they might have been fine for some of the technicians, they would have posed a major learning roadblock for others. As an alternative, we looked at available graphical programming languages and, one by one, we tried most of those available.

Eventually we chose Agilent Technologies' Visual Engineering Environment (VEE).

Building upon VEE we were then able to develop the application we named *The Athena Data Collection, Logging, Display and Distribution System*. Today this system is on board Woods Hole Oceanographic Institution's surface ships – such as *Knorr, Atlantis* and *Oceanus* as well as the research submersible, *Alvin*.

We chose Agilent Technologies' VEE application development language for the *Athena* program for a number of reasons: It seemed to have all the features we knew to be important based upon our previous data-logging program experience. The graphical development process resulted in understandable source code with a high degree of self documentation. It was easy and fun to use which meant the ship's technicians were likely to take an interest in learning more than simply the mechanics of operating our application. Finally, it allows application users to enter more than just variable values; they can enter the equations to be used with these variables. This was critical since it provides the key to allowing field technicians to tailor the application to the needs of particular cruises without modifications to the primary code. For the most part, this can be accomplished without any programming knowledge since the required entries can be simple algebraic formulas or the names of provided functions. More complicated adjustments in the field are also possible because Vee applications can run other Vee applications or programs written in other languages, including the many scripting languages presently available.

> "The [VEE] graphical development process resulted in understandable source code with a high degree of self documentation. It was easy and fun to use."

As a simple example of this last point, it is frequently necessary to extract a value from within a data input string and change the value's format and units, i.e. from psia to depth in meters. The *Athena* application operator uses a built-in configuration editor to specify how the program is to extract the psia value from the input string and to enter the necessary pressure-to-meters conversion equation, all without having or needing access to the Vee program development environment. Once entered, this information becomes part of the application and is used every time depth data is collected. The ability to enter specific information of this type from the keyboard while the program is running is not trivial; VEE allows this, but many languages do not.

What is Agilent VEE Pro?

Agilent VEE Pro is a powerful, productive, easy to use, graphical programming environment designed to save the user time in building and programming test systems. Agilent VEE Pro is the fastest path from measurement to analysis in existence today.

To create a program, you choose high level graphical objects from the menu and connect them with wires (no more low-level icons to represent each textual line of code). The wire connections help specify functionality and sequences in intuitive block diagrams. You program at a higher, task-oriented level using built-in scientific and engineering routines. Agilent VEE Pro jumpstarts the programming effort and keeps it running smoothly for beginning and veteran programmers alike.

Agilent VEE Pro is designed for productive instrument programming. It can talk to any instrument from any vendor using GPIB, LAN, USB, RS-232, VXI and other common backplanes and protocols. Agilent VEE Pro supports industry standard instrument drivers including IVI-COM and VXI plug&play as well as a variety of legacy drivers. Agilent VEE Pro includes nearly a thousand drivers representing the most popular instruments from 70 different vendors. Agilent VEE Pro can control any standard instrument and many vendor's PC plug-in cards.

Agilent VEE Pro interfaces with popular office tools: use Microsoft® Word for reports, Excel for spreadsheets, Outlook for paging and e-mail, and Access for database operations. Agilent VEE Pro integrates the .NET Framework and ActiveX, simplifying common tasks and making powerful system capabilities available to your programs. It is easy to complete tasks such as programmatically managing files, sending an email report, or invoking a web page. With the included Active X Automation Server, other programs can call VEE Pro user functions. Agilent VEE Pro accepts data from virtually any vendors' Instruments, PC cards, and sensors. It supports all popular programming languages including Visual Basic, C/C++, Visual C#, all .NET compliant languages and National Instruments' LabVIEW. It works with surface-mount machines, robots and other manufacturing equipment via the .NET Framework or ActiveX libraries supplied by the manufacturer. And it can be used as a standalone solution or included in a custom in-house solution. Agilent VEE Pro programs can be monitored and diagnosed remotely via the web or network.

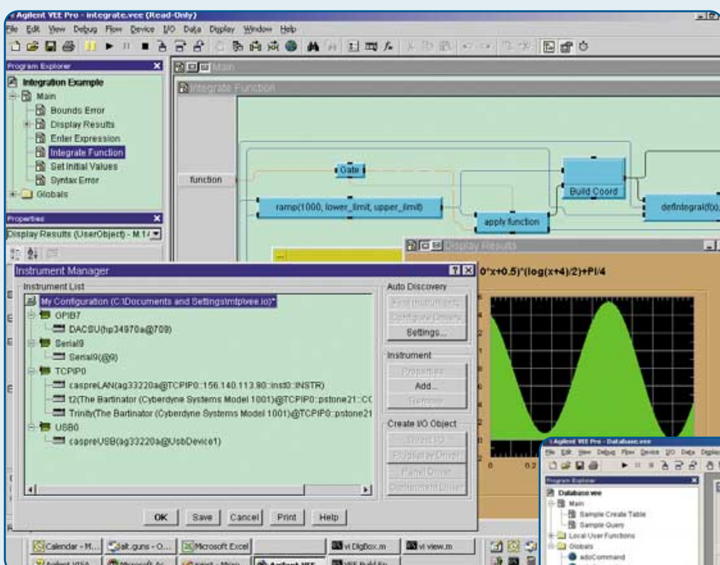

Figure 4.

Agilent VEE Pro optimizes instrument connectivity with its easy to use instrument manager

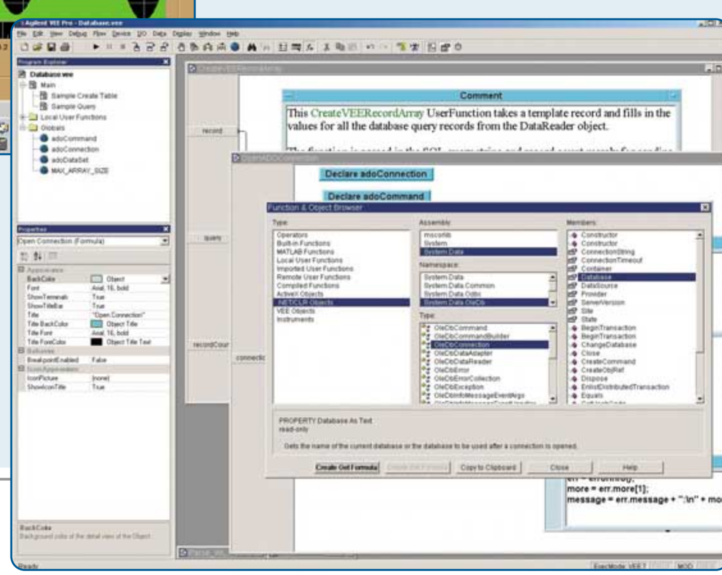

Figure 5.

Agilent VEE Pro utilizes the Microsoft .NET Framework to programmatically access database records

How Athena Works

Figure 5 shows the overall layout of the *Athena* program. First a configuration file is read that gives the technicians the opportunity to control many of the startup parameters. The file specifies the ship's name and its abbreviation, where to store collected data, the type of data files to be generated and, most importantly, the names of the port and transaction database definition files. Following this, the program loads all the "functions" and "constants" located in a pair of pre-defined directories. Next, it runs any executable files found in a third directory, including scripts, batch files and other VEE applications. These steps allow providing the primary *Athena* code with new capabilities and information without changes to the basic code itself. The difficult part is enabling the primary code to take advantage of these additions and this is the role of the application's two major databases.

The Port and Transaction database files contain all the information necessary for the *Athena* code to schedule and complete the activities desired for a particular installation. The port database holds the names of the expected I/O ports as well as their configuration data. As part of the startup process, this information is used to open and validate required port availability. New ports discovered during this process are automatically added to the database along with default initialization information. The transaction database holds the information necessary to define and schedule each of the activities the *Athena* code is expected to perform. This includes sensor and display initializations, sensor interrogation, data calibration and format conversions, mathematical operations, special event responses, log file generation, and re-issue of data for display and use by other applications.

Once started, the *Athena* code enters a continuous loop, which reads the transaction database in a timed sequence and accomplishes the defined tasks. The transaction database contains a record for each of the tasks the code is expected to perform. The fields contained within each record define the expected activity and its timing. Whenever a new sensor or instrument needs to be accommodated, a new record is added to this database and its fields are loaded with the necessary information to enable the primary *Athena* code to understand how to deal with the new arrival. Entries within the database provide all the information for sensor initialization activities, data collection, format conversion, log file entries, and even the metadata associated with the data items.

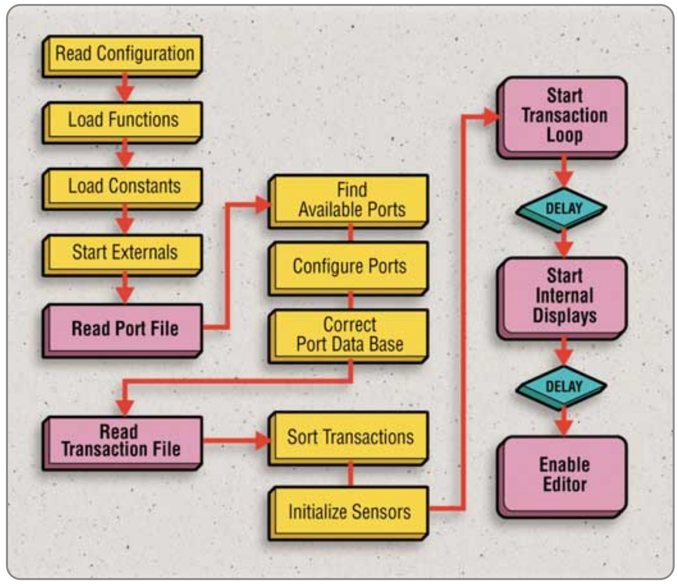

Figure 6. An Overall Layout of the *Athena* Program. Once the initial steps are completed through 'Start Internal Displays', the technician can enable the Editor and perform modifications to the configuration.

The main *Athena* code loop also provides a simple status display to provide assurance that its still functioning and watches for an operator request to change the configuration using the built-in editor. This editor is by far the most complicated component of the *Athena* code. Its role is to simplify the task of correctly maintaining the port and transaction databases. Although these databases are simple text files, the format is critical and the purpose for many entries is not obvious. The editor contains a level of intelligence that greatly simplifies the task of adding or modifying a port or transaction definition by providing extensive entry guidance and error checking. As a result, most instruments can be interfaced using straight-forward entries in a window or by choosing from a provided "selection" list of available alternatives. Functions and constants loaded when the *Athena* application starts, as well as "self identifying" data that arrives unannounced at specified input ports, are automatically appropriately added to the "selection" lists provided to the operator by the editor. This is how new capabilities can be incorporated without changes to the basic code—the editor enables utilizing them in a transaction definition by allowing them to be included in the appropriate database entries. The primary code simply knows what to expect and how to deal with any entry found in each of the database fields.

Some Lessons Learned

Some of the challenges faced and overcome dealt with these issues:

- How could the same *Athena* code be utilized to meet the greatly varying needs of different installations?
- How could the *Athena* code accommodate different instruments from various researchers without requiring "development environment" changes?
- How would a ship's technician be able to make complicated configuration changes with only minimal training and experience?

With regard to the first issue, most oceanographic sensors and instruments use RS232 for data output or they can be connected easily to an interface device having RS232 or RS485 capability – such as a Keithley MetraByte module. Therefore accommodating instrumentation brought on board by cruise researchers is usually a matter of configuring a serial port, arranging for the required command/data exchange at appropriate time intervals, and logging the received data. This is not particularly challenging if the sensors are independent and the idea of maintaining a collection of tailored software applications is acceptable. The key to the success of the *Athena* application is its use of a database structure to organize a large number of these activities.

The second and third challenges are met by providing an editor tailored for use in maintaining the field entries within the databases. This editor, including its extensive entry validation and control features, greatly simplifies the tasks associated with adding new capabilities and making configuration changes without in-depth programming knowledge. It also controls the risks associated with allowing field personnel to modify an application's basic operating code.

Conclusion

The *Athena* application was intended to provide a unifying organization to sensor-specific data collection code while not preventing the flexibility so essential to the diverse applications required by individual researchers. For those sensors that are reasonably standard, *Athena* contains the code required for scheduled I/O transactions. For more complicated requirements, *Athena* enables generating the required interface code with little or no high-level programming.

In the development of *Athena*, Agilent Technologies' VEE fulfilled virtually all of our expectations. It has the necessary capabilities and it is easy for our technicians to learn. It allows development of applications that are both powerful and flexible. Although many of our requirements are not particularly complex when considered individually, they can be difficult when the ship is approaching a data collection station and the field technician has a scientist leaning over his or her shoulder. Having an easily understood, unified interface between the technician and the many activities relegated to the sensor interface and data logging system can make all the difference.

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