MONTSERRAT VOLCANO OBSERVATORY

GOVERNMENT OF MONTSERRAT

Upgrading the MVO seismic data acquisition and analysis systems and collaborating with SRU

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EXECUTIVE SUMMARY

This report explores solutions to upgrading MVO's failing data acquisition and analysis systems. Several systems utilized at different volcano observatories and regional earthquake monitoring facilities have been appraised. In particular, attention is paid to the following as a visit to SRU between 26-30 September 2000. The purpose of that visit was to appraise SRU's Soufriere seismic data acquisition and analysis system, and to discuss data sharing between MVO and SRU. Discussions were held with Dr. John Shepherd and electronics/computer specialist, Chan Ramsingh. Co-operation would be mutually beneficial for both organizations.

Issues addressed in this report are:

- MVO's need to replace the VME hardware currently used for acquiring data from the digital network.
- MVO's desire to combine data from both its digital and analog networks into a single acquisition/analysis system.
- MVO's need to receive real-time data from SRU stations in Nevis and Antigua to improve its capability to distinguish between regional and volcanic events.
- SRU's desire to acquire MVO data, including data from at least one broadband station, in SEED format, to boost its regional monitoring capability.
- SRU's desire to upgrade its Soufriere seismic data acquisition system, which would benefit from a joint proposal with MVO.
- A review of proposed solutions to these problems
- Recommended solution

1 REVIEW OF CURRENT DATA ACQUISITION AND ANALYSIS SYSTEMS AT MVO

MVO is seeking to upgrade its seismic data acquisition systems. Both the PC-SEIS system used for analog data acquisition, and the Seislog system used for digital data acquisition, are having problems.

1.1 Status of the analog network data acquisition system

The analog network acquisition system was installed by the USGS Volcano Disaster Assistance Programme (VDAP) in July 1995. It consists of several PCs:

- PC-SEIS: an event detection system, creating event files in SUDS format. By design, these events are automatically transferred to the BRAINS computer, and then deleted from the PC-SEIS hard drive.

- RSAM: an alarm system which declares event and tremor alarms, call cellphones and pagers, and also records continuous data with a 1 minute sampling rate

- PORKY: which acquires data from slow data rate channels (in MVO's case, tilt-stations)

- BRAINS: the data analysis computer. Events are classified using BUDSPICK, and there is a general purpose analysis tool called BOB for looking at RSAM and TILT data series, as well as other data series manually created by MVO staff, such as event counts or COSPEC measurements

Good points about the system design:

- RSAM provides this system with good real-time monitoring capabilities, which are key to MVO's monitoring programme

- By relying on PCs and DOS/Windows rather than specialist computer hardware and operating systems, the system has been easy to maintain

Weaker points:

- Event classifications have to be manually recorded in a book, and daily summaries of event counts have to be manually inputted into a text file for display by BOB

- There are no tools for spectrograms or other more sophisticated forms of data presentation

Current problems:

- The computer network connecting these PCs has broken down. According to MVO's computer network administrator, the problem is that VDAP system runs on DOS and Windows 3.1, and these can no longer be integrated with MVO's Windows NT network. This means that data have to be transferred manually, by using a single parallel port Zip drive.

- One consequence of this is that BOB can no longer be used to analyse RSAM data in real-time.

- Another is that event data are often lost, since data are no longer transferred and deleted automatically, and the PC-SEIS hard drive fills up. Increasing the storage capacity of the PC-SEIS computer is not possible according to the MVO network administrator, as hard drives are no longer available for this type of PC. It is also not possible to run PC-SEIS on a modern PC, because the PC-SEIS ADC card is not compatible with a modern PC.

- The RSAM computer frequently freezes, most commonly when it is trying to dial a number. Also in a list of 4 numbers, it will almost never reach all 4 successfully, and sometimes will not reach any. This means that MVO is without a reliable alarm system for the analog network.

It would make sense to replace the VDAP system with a new system that can operate on a modern PC, and be easily networked.

1.2 Status of the digital network data acquisition system

The digital network acquisition system was installed by the BGS Seismology Group in October 1996. It wasn't designed for volcano monitoring, but was simply what the BGS had available at the time, and had used for regional earthquake monitoring applications elsewhere. It consists of:

- Seislog: an event detection system, creating event files and continuous data files in Seislog format. This runs on a Motorola computer with a VME bus (this computer is commonly referred to as 'the VME'), running the OS9 real-time operating system.

- A Sun Sparc 5 workstation, running the Solaris operating system. Event classification is performed with Seisan, and a BGS software 'vme_collect' transfers data from the VME, converts event files to Seisan format, and has a menu interface which allows MVO staff to archive data to DDS DAT tapes.

- Currently the data are received via an EarthData Interpolating Line Interface (ILI) which uses the input from a GPS clock to timestamp the data, and also realigns the samples.

Good points about the system design:

- Seisan. This is a much better analysis tool than BUDSPICK.

Weaker points:

- There are no real-time monitoring tools. Essentially it is an off-line data processing system, not really designed for volcano-monitoring applications which by their very nature require real-time monitoring.

- By relying on specialist hardware (the VME and a Sun workstation) and specialist operating systems (OS9 and Solaris), this system cannot be adequately maintained by the MVO network administrator.

- A further consequence of this is it has not been possible to network the VME or the Sun with the rest of the MVO computer network. Since a Zip drive cannot even be attached to these machines, and they both lack a CD writer, it makes data transfer with other MVO computers very difficult.

- Tools for data analysis, beyond event classification and hypocentral determination either do not exist, or are so convoluted and tedious to use that they are impractical.

- Data archival is very poor. The vme_collect software does nothing to verify that (i) there is a tape in the drive, (ii) the tape is forwarded to the end of data already recorded on it, (iii) data are recorded safely, before deleting them. Massive data loss (approaching 50%) has occurred as a result over a prolonged period.

Current problems:

- The VME has become extremely unstable since Y2K. It has crashed up to 25 times in a single day, and has to be manually restarted each time. Even with regular checks and reboots, data loss in recent months has average 16% which is at least two orders of magnitude too high.

- The Sun workstation is showing its age. The monitor has some damaged cabling, resulting in a purple on pink display which is not ideal.

- Due to the lack of data analysis tools, the Seismologist has been compelled to invest his own money in a personal laptop, and used his own copy of Matlab to developed an array of tools for plotting seismic parameters such as event counts, event energy, hypocentral plots, spectrograms and pseudo-helicorder plots.

It would make sense to replace the VME and Sun workstation with modern PCs. The new system should provide real-time monitoring tools. An alarm system is already being developed at MVO, as is more robust data archival system. The acquisition of a Matlab licence would allow tools developed on the Seismologist's personal laptop to be utilized on the MVO computer network. Finally, more hard drive space is required so that on-line databases of the raw seismic data can be established.

2 SYSTEM DEVELOPMENT CONSIDERATIONS

MVO seismic monitoring is the backbone of MVO operations, and plays a significant part in safeguarding the population of Montserrat, and regional aviation. There are therefore several important things to bear in mind when considering upgrading the current systems:

1. Of highest importance, it is vital therefore that robust data acquisition and alarm systems are established. These should be backed up by individual UPSs. They should ideally run in failover mode, i.e. two data acquisition systems running in parallel. All critical software should automatically reboot and restart in the event of power loss. Moreover, the development of a diagnostic alarm system has begun which monitors potential points of failure in the data acquisition and alarm systems, and alerts the Seismologist by pager. Finally no other processes should be allowed to interfere with these systems, i.e. unnecessary processes should not be run on the host machines.

2. It is important to put in place alarm response systems / real-time monitoring tools. The most effective way to do this is by hosting seismic data (e.g. spectrograms, RSAM plots, digital helicorder plots) on an internal web page that MVO staff can check from home. Currently it can take up to 20 minutes for staff to drive into the observatory, and this slow response could be significant for aircraft traveling at

10 miles per minute towards an ash cloud. Moreover, alarms are frequent – it is not unusual to have to respond to 3 or 4 alarms per day, for months on end, so it is a huge inconvenience for staff to always have to drive in to check seismic data, and doesn't allow them to be as productive at work the following day. A remote monitoring webpage would therefore be a valuable development.

3. Better data analysis tools should be put in place. A few months ago, tools even for generating a simple plot of event counts were convoluted. Since then Matlab tools with simple GUIs for plotting event counts, event energy, RSAM, tilt, hypocentral data and spectrograms have been developed. To have these user friendly tools like this available means that the Seismologist can make a much more detailed analysis, view a wider range of data and seismic parameters, and do so quickly. However, these tools are somewhat ad-hoc at present. The purchase of a Matlab licence will mean that these can be hosted on an MVO PC rather than my personal laptop, allowing better integration with other analysis software such as Seisan.

4. All data should be archived using a single utility. In recent weeks, a new archival tool (archive2dat) has been written which is used to archive data from the digital network. Unlike its predecessor (vme_collect), archive2dat performs many checks: (i) that a tape is in the drive, and it's a DDS tape, (ii) it automatically moves to the end of data on the tape, (iii) every time a data file is written, it is verified, (iv) it keeps track of what data have been successful written to file. This should significantly reduce data losses due to data archival problems, which have been around 30% in the previous 12 months.

5. It makes sense, wherever possible, to utilize software available from other organizations or communities, rather than reinventing the wheel. While no complete off-the-shelf solution is available, systems available from other volcano observatories or regional earthquake observatories usually present a good starting point that can be tailored for our needs. For example, the US volcano observatories are all now running the USGS Earthworm system, and their Volcano Disaster Assistance Programme (VDAP) has installed this system in observatories in Central and South America.

6. It also makes sense to use PC technology wherever possible. A significant problem with the digital seismic network equipment installed by BGS in 1996 has been the lack of on-island support for specialist computer hardware (the VME computer and the Sun workstation) and specialist operating systems (OS9 and Solaris). Moreover, the MVO Network Administrator (Dave Williams) is trained in Windows NT, and could provide far better support and reliability if the seismic

systems used this. Linux may be the best alternative where greater robustness is required, or a Windows version of the software isn't available.

7. The ability to share data with regional agencies is highly desirable, though not essential for a volcano observatory. Technically, this should not be difficult to achieve, and better collaboration between SRU and MVO would be of mutual benefit.

3 REVIEW OF AVAILABLE DATA ACQUISITION SYSTEMS

MVO has appraised the following systems: ViSeis, IceWorm, EarthWorm/GlowWorm and Soufriere, SA24, Scream and two Seislog-based proposals by BGS. Table 1 shows how these stack up against each other. Whichever solution MVO adopts, it is keen to retain Seisan for routine analysis of volcano-seismic data, and which feeds into a number of Matlab-based tools.

	PC-SEIS	**SEISLOG**	**SA24**	**ICEWORM**
analog data?	yes	yes	no	yes
digital data?	no	via ILI	via ILI	via Scream
Alarm?	yes - problems	no	no	yes
Event triggering?	yes	yes	yes	yes
Continuous recording?	no	yes	no	yes
Relation database?	No	No	no	yes
real-time tools	RSAM & seismograms	none	none	RSAM, SSAM & seismograms
dial-in server	no	none	none	2 day WaveTank
OS	DOS	OS9,QNX, Windows	Windows 98	Solaris

author	USGS/VDAP	University of Bergen	EarthData Ltd	USGS/AEIC
Cost	Free	Free	Free ?	Approximately $30000 for an Antelope licence

	VISEIS	**SCREAM**	**SOUFRIERE**	**EARTHWORM / GLOWWORM**
SP data?	yes	yes	yes	yes
BB data?	? via Scream	yes	no	via Scream
Event triggering?	yes	Limited	Yes	yes
Continuous recording?	yes	Yes	yes	yes
Relational database?	No	no	no	yes
Alarm?	no	no	no	No
real-time tools	seismograms	seismograms	Text-based RSAM & SSAM	RSAM, SSAM & seismograms
dial-in server	none	5 hour WaveTank	none	5 hour WaveTank
OS	Windows 98	Windows NT	DOS	Windows NT
author	PC Systems	Guralp	SRU	USGS/VDAP
Cost	From $1300	Free	Free – but needs upgrading, and this is expensive	Free

Table 1: Review of data acquisition software. Note that SA24 is really only intended as a front-end for getting data from EarthData telemetry into Earthworm. Scream is only really-intended as a front end for receiving data from Guralp digitisers, although it does provide limited event triggering capabilities.

3.1 PC-Seis

The problems with PC-SEIS have been adequately covered in section 1. It cannot be considered part of the solution.

3.2 Seislog

Seislog is a simple and effective event triggering and continuous data recording software system. It is free, and can run on a variety of platforms, including Windows. It could be a component of a solution, though it lacks tools for real-time monitoring.

3.3 SA24

SA24 is software produced by Earth Data, and is a front end for receiving data from the Earth Data radios and ILI. So it is better considered as part of the Earth Data telemetry system rather than a data acquisition system.

3.4 Iceworm

Iceworm is a system developed at the University of Alaska, which merges the USGS Earthworm system with the commercial Antelope software and Datascope relational database system from Boulder Real Time Technologies. It is probably the most advanced solution, and the Alaska Volcano Observatory has built powerful real-time monitoring tools based on it, including “IceWeb”, which could be used at MVO. However, the significant drawback of the Iceworm system, is the licencing cost for Antelope/Datascope, which is around $30,000.

3.5 Viseis

Vi-Seis is a system developed by experienced USGS seismologists, who formed PC Systems Ltd. It seems a simple system to operate. Its not clear how whether it is compatible with Scream.

3.6 Scream

Scream is system written by Guralp systems which can be used to acquire data from Guralp seismometers and other devices including slow data rate channels. A Scream only solution is possible, as Guralp digitisers can do event triggering in the field. However, practically it is better to think of Scream as a front end for importing continuous data into software like Earthworm.

3.7 Soufriere

3.7.1 Current setup

The Soufriere system consists of three main parts:

1. Data acquisition:

The data acquisition is done using the MONITOR system, a very stable DOS-based program which runs under a Windows-95 shell. It has sophisticated frequency-dependent LTA:STA detection algorithms which could be tuned to detect specific types of events such as volcano-tectonic or long period earthquakes, which was developed due to limited memory and hard-drive space during the 1970s. There is a text display of RSAM and SSAM data, and the system learns continuously about the background seismicity level and adjusts the triggering thresholds accordingly. The system can record continuous data, although SRU don’t operate it in this mode. GPS time is stamped on the data every 4 minutes, and anomalies between GPS time and PC time are flagged. When the signal drops below a user-defined level, data are ignored. Also if data exceed the threshold for a long time, warnings are given since this is most likely due to a telemetry problem.

MONITOR PCs are set up on most islands in the Eastern Caribbean and SRU’s usual setup is install a Guralp broadband seismometer adjacent to the PC, acquired through an onboard A2D converter, with a network of analog telemetred short-period seismometers. All data are stored locally in a ring buffer, which gives some ability to recover lost data.

2. Data analysis and phase picking:

Data analysis and phase picking is done using the PLAYBACK system. The fundamental idea behind this system is that triggered data from MONITOR PCs on all the islands in the Eastern Caribbean can be downloaded (using ftp or a dial-in modem) and then ‘replayed’ as if they had been recorded on the same PC. These data communications are done using LAPLINK. This also allows SRU to change settings on the remote MONITOR PCs on the fly, and do troubleshooting if necessary, without the need to leave Trinidad.

Events for analysis are selected through an MS-ACCESS interface, as is the ‘save file’ to archive the useful traces. These ‘save files’ consist of multiple events, and are more akin to multi-event tar files at MVO. REPLAY, the phase picking software, is a DOS application running under a Windows-95 shell. The software has all the features one would want, such as filtering, zooming, FFT etc., but this is done using the keyboard rather than the mouse, and is consequently not as quick or as user friendly as the BUDSPICK and SEISAN programs that MVO presently uses for analyzing data. This is more of an issue for MVO than for SRU, since MVO typically records hundreds rather than a few events per day. There is a no way to assign weights to picks within REPLAY, but this can be done at the next stage (WURST).

There is a facility for exporting data to Matlab, which displays the acceleration, velocity and displacement seismograms, allows picking, shows FFTs and automatically computes Brune magnitudes, which can be compared with the coda magnitudes computed with REPLAY.

3. Hypocentral determination

The final part of the Soufriere system is WURST. This is a DOS program, which can be run from a Windows-95 command prompt. The system has a great feature – it does not use layers of constant velocity, rather it uses a velocity function $v = Ar^B$ for each layer, which results in a velocity structure without any first-order discontinuities. This is good since it prevents biasing of earthquake depths to the discontinuities between adjacent layers – i.e. the locations are likely to be more accurate. Origin time is computed using S-P times at different stations, which helps the solution converge to the correct local minimum in 4-D space. The algorithm also outputs a condition number, in addition to the usual rms error between predicted and picked arrival times. Only if both numbers are small is the solution a trustworthy one. These features make WURST preferable to commonly used programs such as HYPO71 and HYPOCENTER, which are presently used at MVO.

A related program is JHD, which stands for Joint Hypocentral Determination. The idea behind this is that the more degrees of freedom you have, the more parameters you can solve for. Hence it is possible to solve for parameters of the velocity model in addition to the usual hypocentral parameters. By combining phase pick data from multiple events, the velocity model and hypocenters can be improved iteratively.

3.7.2 Changes to the Soufriere system

Changes to the Soufriere can really only be undertaken by David Beckles, the original author of the system, who charges a consultancy rate of 10000 GBP per month. This is in large part because Soufriere, although written in C, has numerous assembly language patches, which makes it impossible for most modern-day programmers to modify the code.

David Beckles is presently altering the MONITOR system so that it writes out triggered files in SEED format. REPLAY will also be modified so it can read data in SEED format. This work has already been paid for.

SRU would then like to alter REPLAY so that it is mouse-driven, which should make it somewhat more user friendly and efficient. At the same time SRU would like to build in better tools for volcano monitoring, which MVO is well placed to write the requirements for. This would assist SRU in future volcanic eruptions, e.g. Dominica. John Shepherd suggests that this work could probably be completed by David Beckles in about 6 weeks, which would cost around 15000 GBP.

Ideally the Soufriere system would be altered so that it runs as a true Windows application. This is important since as a DOS-application, the Soufriere system may not operate under future versions of Windows, and MVO (and SRU) could get into similar legacy problems as it now has with its PC-SEIS system (parts of which will run only under DOS, or Windows 3.1). However, David Beckles has estimated that to rewrite the Soufriere system to run under Windows would take about a year, which at his consultancy rate would cost over 100000 GBP.

MVO would also need some way of feeding in data from its digital network into Soufriere. Rather than working on an ILI-Soufriere interface, which would likely take many weeks, it would probably be cheaper to acquire the data using Scream (see "Acquiring data from the digitally-telemetred network").

3.8 Earthworm/GlowWorm

The GlowWorm system is VDAP's replacement for the PC-SEIS system, and extends the USGS' new regional earthquake seismic monitoring system system "EarthWorm", by adding modules that are tailored for volcano monitoring. The GlowWorm system is still under development. The acquisition software includes much improved RSAM and SSAM tools. The alarm system, and the analysis software (BUDSPICK and BOB) are still the same as used with the PC-SEIS system, though upgrades are planned to these. User friendly diagnostic and system configuration tools have been added.

The system is modular and the source code is made available, allowing users to add on modules of their own which they are then encouraged to share with the whole Earthworm community. There are already modules which plot daily spectrograms and pseudo-helicorder plots as gifs images, allowing them to be displayed on the Web, which helps for remote monitoring.

MVO would prefer to use SEISAN rather than BUDSPICK for event classification, and has contacted Tom Murray, who leads the GlowWorm project, to see if it is possible to make GlowWorm and SEISAN compatible. This seems to be a trivial data conversion issue: Earthworm can already write triggered files in SAC format, which SEISAN can read.

GlowWorm has been installed at several observatories, and Scream is used as a front-end for acquiring the broadband data. A conversion program therefore already exists. MVO would employ this method for getting data from its digital network into GlowWorm.

Earthworm/Glowworm requires only a modest PC with Windows NT, which would only cost around $1500.

For acquiring data from the analog network, there are two simple methods. Method 1 would use a new ADC card available from National Instruments for about $1600, and then the Earthworm adsend module to import the analog data. This is the method recommended and used by the Volcano Disaster Assistance Programme (VDAP). A second method would be to purchase two of Guralp's 8-channel digitisers rack, which output data in gcf format, which Scream can read. The cost would be $2700 US for each unit.

4 REVIEW OF DATA ANALYSIS SYSTEMS

The choice of a data analysis system is rather simpler. There are three main choices:

1. Seisan: The University of Bergen software MVO has used for analysis of digital network data since October 1996. A number of Matlab tools have been developed on the back of this to better tailor it for rapid data analysis and volcano monitoring. Seisan has the advantage of being familiar to MVO staff.

2. Budspick: The software that was installed by VDAP, and will also work with GlowWorm "out of the box". This has the advantage of already being familiar to MVO staff, but the lack of an event recording facility is serious. The BOB software, while useful in the past, is far less powerful than Matlab programs which now exist, and in any case does not appear to have been used for integrated monitoring for at least 2 years (other MVO scientists prefer to use Excel for data analysis).

3. Replay: The SRU software, which also is packaged with WURST (for hypocentral determination) and some Matlab tools. An advantage of this system could be long-term compatibility and collaboration with SRU. The WURST system is probably the best earthquake location software available. A

disadvantage could be the learning curve, though this would probably not be too steep.

Based on considerations like features available, compatibility, familiarity and operating system, Seisan has a clear edge for event processing. However, it might be worth trying to interface Seisan with WURST for better hypocentral determination.

	SEISAN	**BUDSPICK**	**REPLAY**
OS	Windows NT,Solaris,Linux	DOS (under Win 3.1) but mouse driven	DOS (under Win 95) not mouse driven
FFT	yes	no	yes
filtering	yes	no	yes
speed	fast	fast	slow
Integrated data analysis	SEISAN + Matlab tools developed at MVO	BOB	WURST + Matlab tools developed at SRU
layers	fixed velocity	fixed velocity	graded velocity
solve for velocity model?	no	no	yes
packaged with	standalone, or with SEISLOG	PC-SEIS, GLOWWORM	Soufriere

Table 2: Summary of capabilities of different data analysis systems.

5 ACQUISITION OF DIGITALLY TELEMETRED DATA

It cannot be overemphasized that presently MVO is reliant on Earth Data telemetry equipment. Any new acquisition system either has to interface with this, or new telemetry equipment will have to be purchased and installed.

Data from the MVO digital seismic network is presently time-stamped using an Earth Data Interpolating Line Interface (ILI) unit at MVO. The data is then passed to the VME, which is not Y2K-compliant and crashes frequently, and has to be eliminated. BGS have attempted to interface a QNX system with the ILI, but this failed. There are three solutions under consideration that wouldn't require new telemetry equipment:

(1) BGS' present proposal to interface Earth Data's SA24 system with the ILI. This seems like a simple solution which wouldn't affect the data quality. An interface could then be created between SA24 and Earthworm, Soufriere or some other acquisition system.

(2) A second solution would just be to write a driver to take the data from the ILI directly into the acquisition system, without using SA24 as part of the solution.

(3) Finally, at MVO the digital data could be converted back to analog signals using a DAC and then redigitised to a common time base. This would result in loss of dynamic range and perhaps introduce an extra source of noise, and would therefore be undesirable (it would eliminate the main benefit of the digital network).

If new telemetry equipment is required, it might be better to timestamp the digital data in the field. MVO presently has Earth Data digimods. These could be replaced by Guralp (or other brand) digimods which accept a time signal from a GPS receiver. Guralp's "Scream!" software could be used at MVO for acquiring the data from a multi-port serial board. The Guralp digimods allow transmission of triggered and/or continuous data, at different sample rates if necessary. Scream itself just logs all incoming data, gives a real-time display, and allows the data to be archived in miniSEED or SAC format, and broadcast on an IP network. Software already exists to feed these data into Earthworm (and therefore Iceworm and Glowworm). Alternatively laptop computers could be used at each site to acquire data, but these would be very difficult to maintain since the average laptop is hardly field-rugged. The Guralp digimods cost about 1600 GBP each.

Total costs for digimods would be 16000 GBP (including 2 spares) plus a further $1000 US for a multi-port serial board. A new PC (for running Scream) has already been acquired as part of the QNX/SA24 project (presently at BGS Edinburgh).

Regardless of the method used, it would be advantageous to use duplex radio telemetry. This would allow MVO to check battery voltages and other diagnostic information, and change digitiser settings, without using the helicopter and would therefore save money in the long run. One option that should be considered is to use spread-spectrum radios which are much more convenient than fixed-frequency radios and can transmit data at higher baud rates. FreeWave radios are the market leaders and cost $1300 US each. MVO would need about 20, so the initial outlay would be in the region of $25000 US for duplex radio capability. This is perhaps more of a long-term solution.

6 COLLABORATION WITH SRU

An important issue to consider when upgrading the acquisition systems is to facilitate data sharing with the SRU (and possibly other regional agencies).

6.1 SRU needs

To enable SRU to do its regional monitoring there is a requirement for MVO to provide SRU with triggered data from at least one broad-band data in addition to some short-period stations. This can be achieved in three ways, listed here in order of increasing desirability:

(1) Use real-time telemetry to send data to a MONITOR on Antigua. This is the method currently employed, and the telemetred stations are MRYT, MJHT and MGHT (all short-period stations). SRU would like to supplement this with one broad-band station.

(2) MVO could convert its data into SEED format, and ftp this to either the IRIS server, or (more usefully) to a similar SRU system.

(3) Acquire MVO data using a Soufriere “MONITOR”. SRU would then be able to auto-ftp the triggered data (in SEED format) to Trinidad for analysis.

Either of plans 2 & 3 would enable SRU would like to setup a similar system to the IRIS Wilber system whereby individual observatories (in this case, SRU, MVO, IPG and the Venezuelans) ftp their triggered data in SEED format to a common site (logically SRU is the best host for this site). This would also make it unnecessary for MVO to send Seisan triggered files on DAT tapes to SRU, which are of little practical use to SRU anyway.

Unfortunately the practicalities of sending SRU triggered data by ftp are rather difficult. MVO’s connection to the internet is rarely better than 6000 baud. MVO typically records 200 triggered files each day, with an average size of 500 kB, i.e. 100 MB per day. Hence the data would take 100000*8/6 seconds to download, i.e. 37 hours, which is impossible. Hence it will be necessary for MVO to have a much faster connection to the internet. Fortunately the University of the West Indies is installing a 500 kbaud network throughout the Caribbean, and if MVO could use this, ftp transfer of triggered data to SRU would become practical.

6.2 MVO needs

MVO needs an improved ability to distinguish between volcanic events and regional earthquakes. This can be achieved in two ways:

1. Data from SRU stations on Antigua and St. Kitts/Nevis could be relayed in real-time and fed into PC-SEIS or its successor, allowing rapid distinction between regional and shallow and deep volcanic events to be made.

2. If MVO installs a MONITOR, then triggered data could be downloaded within minutes from MONITOR computers in Antigua, Dominica & St. Kitts if necessary, and analysed using REPLAY (which is necessary for combining data from different MONITOR computers). This would give MVO the capability of locating deep events under Montserrat and other events within (say) 50 km of Montserrat. In this case it would still be desirable to have data from at least one SRU station telemetred to MVO in real-time.

SRU would not attempt to analyse Montserrat volcanic data routinely, and has no desire to do so anyway, since it does not have the resources. Likewise MVO would not release information on magnitude or hypocentre to the public or media, since this is clearly SRU's responsibility. MVO would also be happy to collect intensity reports for felt events on Montserrat on behalf of SRU.

7 PROPOSALS

7.1 Modified Soufriere System

If MVO were to adopt the Soufriere system as its primary acquisition system, this is how I would propose doing it, bearing in mind the need to combine data from both the analog and digital networks:

1. Install Guralp digimods and GPS receivers at stations on the digital network. Acquire the digitally-telemetred data using Guralp's "Scream!" software.

2. Connect a Soufriere MONITOR to the output of the PC-SEIS discriminator/digitiser box, so that MONITOR acquires the data from the analog network. Data from the on-site broadband seismometer (MBMH) would be fed directly into MONITOR, and triggered data would be written out in SEED format (and copied into Seisan format). Parts of PC-SEIS (e.g. BOB and the RSAM

alarm system) could continue to be used. Event classification using BUDSPICK would certainly be discontinued, although these data could continue to be archived. Continuous data recording from the MONITOR system should be enabled. MONITOR should also be modified so that RSAM and spectral data are continuously archived to a Matlab database. Data from at least one SRU short-period station, probably NEV, would also be telemetred in real-time and acquired by the MONITOR computer.

3. Convert triggered data to SEISAN format, and use SEISAN for routine event classification. Derivative event data would still be computed using 'ampengfft' and written into a Matlab database. SRU would provide a free copy of Matlab, worth $6000 US to MVO. An association algorithm would have to be written to enable triggered data from Scream and analog data from MONITOR to be combined.

4. Hypocentres would be computed by picking phases with REPLAY (downloading data from Antigua, Nevis and Dominica as necessary) and running WURST.

The cost for the Soufriere hardware would be approximately $7000 US. Modifications to the Soufriere system, including a mouse-driven version of REPLAY and the RSAM and spectral output would probably take 6-8 weeks, and therefore cost 15-20000 GBP at David Beckles consultancy rate. This is in addition to costs for upgrading the digital network [Section 5].

7.2 Earthworm/GlowWorm System (upgrading the telemetry)

If MVO were to adopt the Earthworm/GlowWorm system as its primary acquisition system, this is how I would propose doing it, bearing in mind the need to combine data from both the analog and digital networks:

1. Install new Guralp digimods and Freewave telemetry, replacing the current Earth Data telemetry system for the digital seismic network.

2. Install Earthworm/GlowWorm acquisition system on a new NT workstation. This would give the superb real-time analysis RSAM and SSAM tools, as well as the 5-hour dial-in wavetank and web-based spectrogram and helicorder modules which would be so useful for remote monitoring.

3. Acquire the digitally telemetred data using Scream and then feed into Earthworm/GlowWorm. A scream2earthworm conversion program already exists and is used at other observatories.

4. Acquire the analog telemetred data using the new EarthWorm ADC card from National Instruments and the adsend module. EarthWorm would then be able to trigger on data from both networks, giving MVO the advantages of better event detection with fewer false triggers, and better hypocentral determination (because of the additional station locations available).

5. Add in one SRU station (e.g. NEV) to the analog datastream, to allow better discrimination between nearby regional and volcanic earthquakes.

6. Auto-ftp the GlowWorm triggered (and continuous?) data to the data analysis workstation and convert to Seisan format. Auto-ftp the RSAM and SSAM data to same workstation and place into a Matlab database. Ftp (e.g. with Perl's FTP module) is more robust than mounting drives.

Costs:

The cost for an EarthWorm ADC is about $1600 US. An acquisition NT-workstation would cost about $1500 US. This is in addition to costs for upgrading the digital network [Section 4], if compatibility with the ILI is too difficult.

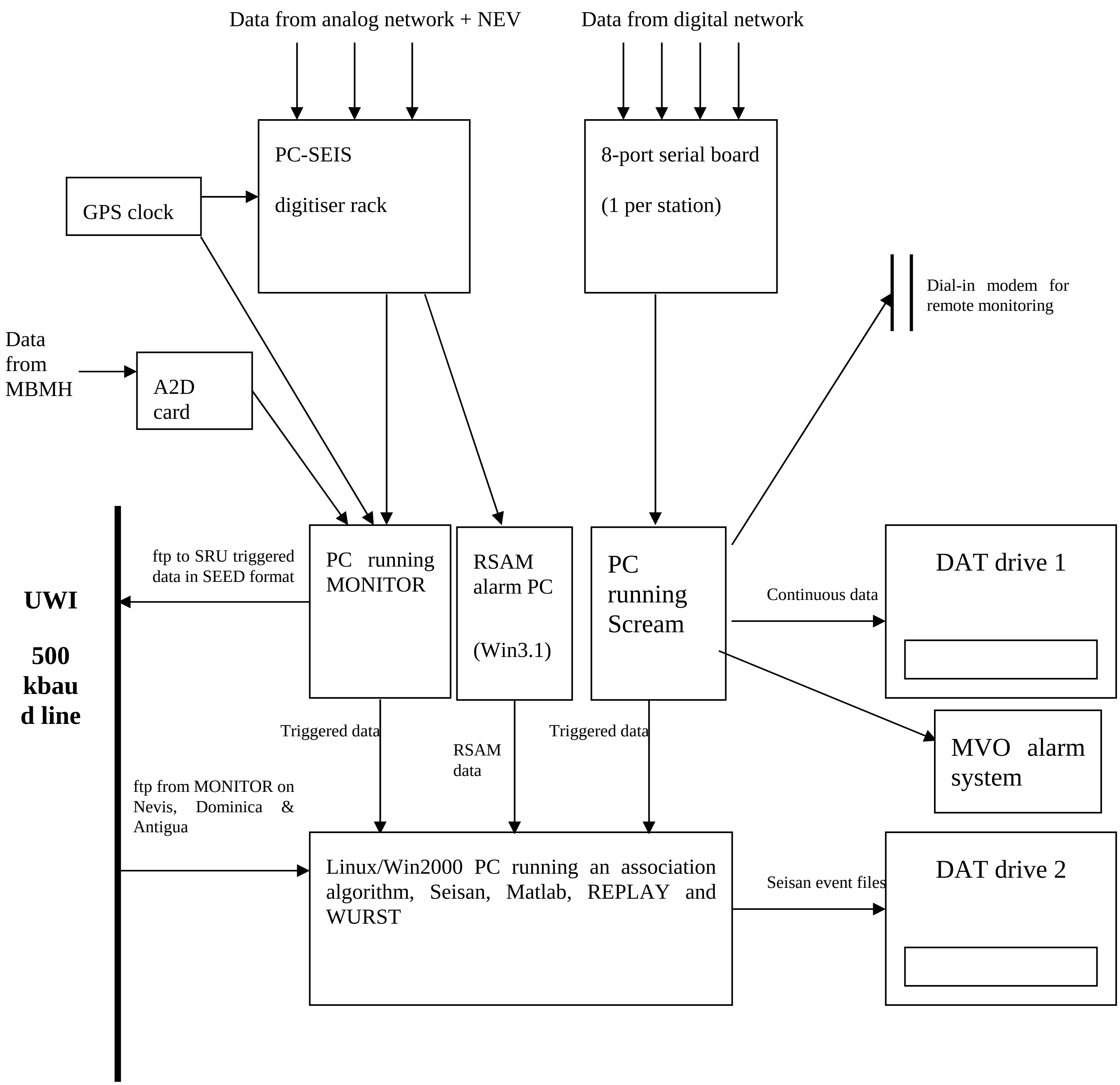

Figure 1: Proposed modified Soufriere solution

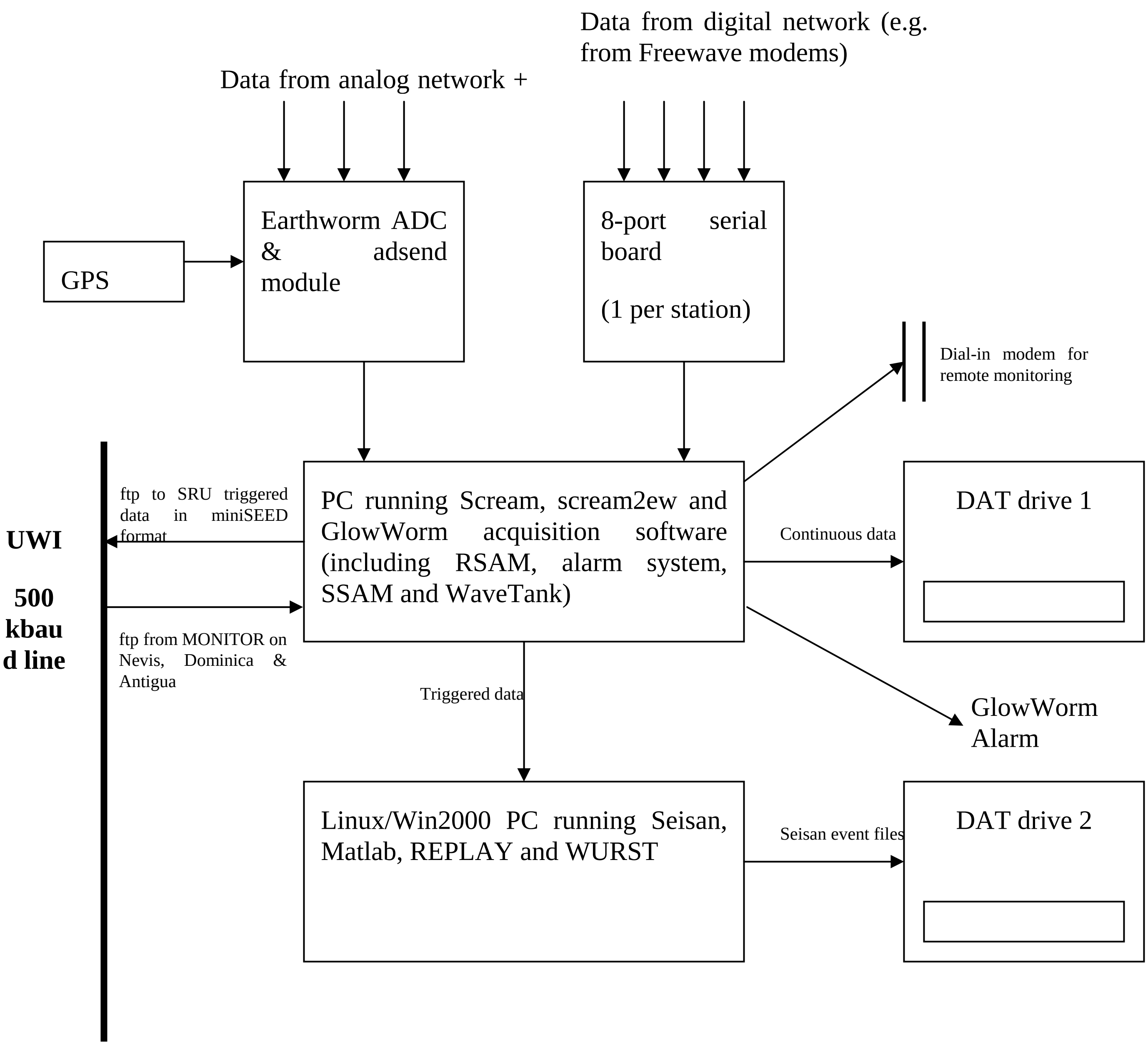

Figure 2: Proposed Earthworm/GlowWorm solution

7.3 Earthworm/GlowWorm System (without upgrading the telemetry)

BGS Seismology believe that the most rapid solution for upgrading the digital seismic acquisition system would be to use the EarthData SA24 software to read data from the ILI, and then write a driver to transfer this data to Earthworm. The SA24 system is what BGS Seismology have been working on since the QNX solution ran into problems earlier in the year. They have also asked EarthData to modify the SA24 system so that it writes out data in a format that SEISAN can interpret, and are also working on difficulties interfacing SA24 with an ILI unit at Murchison House, which like the MVO ILI was modified from its original EarthData configuration. BGS Seismology cannot estimate a delivery date for the system to MVO, and MVO cannot afford to wait long for a replacement for the VME unit given what is at stake.

If there is some breakthrough with the SA24 proposal during the next month, MVO will reconsider it. However at present this doesn't seem likely.

8 RECOMMENDATION

It seems clear that MVO will eventually have to upgrade its broadband network in the way describe in Section 4. As pointed out, it would make sense to use duplex telemetry since in the long run this would save money. Guralp are drawing up a costed proposal for the (mainly telemetry) equipment needed and an installation visit if necessary. Guralp have also made a generous offer to install the equipment for free on a test it first, pay later basis.

It is also clear SRU would like to install a MONITOR system at MVO, since this would improve their capability to locate regional earthquakes in the Leeward Islands. This would benefit MVO by providing a backup acquisition system for the analog network, and help MVO discharge its duty to provide SRU with triggered data. However, for any of this to be any use, MVO would need to be connected to the University of the West Indies Caribbean-wide 500 kbaud network. With this in place, MVO would benefit from running SRU's REPLAY and WURST software, which would improve MVO's ability to locate events (particularly deeper events under the volcano) and distinguish between regional and volcanic events. But REPLAY should be altered so that it is mouse rather than keyboard driven, since this is something both SRU and MVO would find desirable. MONITOR would also have to be modified to include a simple alarm system that can trigger an alarm on the basis of RSAM data, and eventually (though not immediately) it would be desirable to run MONITOR as a DOS-application under Windows, rather than under DOS 6.

The question is, how much would this work cost? The estimates provided by John Shepherd of 2 months at a rate of 10000 GBP per month are excessive. Moreover the real-time analysis features offered by GlowWorm would greatly benefit MVO. GlowWorm is also a true Windows application and many more powerful features are likely to become freely available over the next few years. And it should be relatively easy for the MVO seismologist to add new modules, whereas any work to add features to Soufriere would have to be contracted out. GlowWorm also includes slow acquisition channels for tilt stations and other data. Soufriere does have some very impressive features that GlowWorm does not provide, e.g. the ability to download data from other islands, and the hypocentral determination algorithms, but on balance, the GlowWorm system is likely to be cheaper and offers much more of the features that MVO needs.

So my recommendation is for the Scream/Earthworm/GlowWorm combination which requires new telemetry equipment (section 7.2).

There are some additional recommendations:

1. MVO should continue to do its event classification using the very popular Seisan software. This will require a conversion program to be written to convert GlowWorm/Earthworm data into Seisan format, which as mentioned above, should be trivial since Earthworm already writes SAC data and a SAC2Seisan converter exists.

2. Event location would best be done using Soufriere's REPLAY software. MVO should seek to get a copy of this and the JHD software, which should be free. No additional hardware would be required. This could be tested. If it doesn't work, the fallback could be to continue to use Seisan for hypocentral determination (Seisan will certainly continue to be used for event classification).

3. Two windows compatible DDS DAT drives should be used for data archival. The current DDS drives cannot be configured to read old data on a Windows-based operating system.

4. Signals from SRU stations on Nevis and Antigua should be acquired in real-time and plugged into the EarthWorm digitizer through the adsend module. SRU have already approved this, and it would greatly enhance MVO's ability to discriminate between volcanic and nearby regional events.

5. SRU have offered to provide MVO with a free (legal?) copy of Matlab. This would benefit MVO a great deal (MVO has already developed a wide range of Matlab utilities for plotting RSAM data, event counts, event energy and hypocenters, but strictly these can only be used on my personal laptop).

6. MVO should willingly provide triggered data in SEED format to SRU. One way to do this would be to host a Soufriere MONITOR at MVO (at SRU's expense). Another way would be to convert GlowWorm (or Scream) data to SEED format. MVO would also need a connection to UWI's 500kbaud Caribbean-wide network, which SRU have offered freely, and would benefit MVO in many other ways as our current connection speed is rarely better than 4 kbaud.

7. MVO should seek to obtain a minimum 30% level of spares for all essential seismic monitoring equipment. For mission critical ADC's which we currently only have 1 of, a spare should be obtained. New uninterruptible power supplies should be obtained for all mission critical computers, given that old ones have not been maintained, and brownouts are frequent. The first step is to assess the current level of equipment – information that the Electronics Team have been asked to provide on several occasions over the past several months.