MONTSERRAT VOLCANO OBSERVATORY

GOVERNMENT OF MONTSERRAT

Upgrading the digital seismic network at MVO: progress 2000-2003

Glenn Thompson

MVO Open File Report 04/05

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Montserrat Volcano Observatory
PO Box 292
Montserrat
West Indies

Tel: 1 664 491 5647
Fax: 1 664 491 2423
Email: mvomail@mvo.ms

* Affiliation inside cover

Affiliation of author

Glenn Thompson
Montserrat Volcano Observatory
Flemings
Montserrat
West Indies

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Executive Summary

In January 2000, MVO was in great danger of losing valuable seismic data. Arguably these data were not just the most valuable dataset collected at the MVO, but they represented one of the most valuable datasets of a volcanic eruption for the advancement of science.

1 INTRODUCTION

The digital seismic at MVO suffered serious failures at the Y2K transition, and the recommencement of the eruption of the Soufriere Hills Volcano made it imperative to fix these problems. The most serious problems were with the VME, which had to be manually restarted up to 25 times a day. 16% downtime was experienced as a result in the first 6 months of 2000, and it seemed likely there could be a terminal failure of the VME at any time, from which it might take several months to re-establish data acquisition once more. In the meantime MVO's monitoring ability would be severely compromised, particularly as its analog seismic network had also been impacted by serious Y2K problems.

Moreover, certain limitations of the original digital seismic network, such as its lack of real-time monitoring tools, tools for analysing continuous seismicity, and poor data archival software needed to be overcome. As a result of the latter, there was approximately 50% data loss in the 12 months beginning June 1999. The ailing Sun workstation along with its DAT drives and vme_collect software needed to be decommissioned. A modern range of volcano-seismic analysis software needed to be developed along with an effective alarm system.

Ultimately the demand for a seismic network that would be sustainable in long-term led to a need to replace the now obsolete Earth Data telemetry system (including the ILI) with a modern, well supported, duplex telemetry system that would enable station health to be determined from the MVO, thus saving considerably on helicopter time and allow a larger degree of preventation maintenance.

Important constraints were that any new systems use PC hardware rather than specialist computer hardware, and Windows NT/2000 or Linux, rather than specialist operating systems wherever possible, since these could be much more easily supported on Montserrat.

Section 2 describes the upgrades from the Sun workstation to a Linux PC, from the VME to the SA24/Earthworm system, and the proposals for upgrading the telemetry in quasi-chronological fashion. Where helpful, key emails are inserted. The sections that follow duplicate key documents that influenced the decisions taken. The aim is to provide an overview of the motivations that led to the interim solution in March 2001, and the international tender and ultimately successful MVO proposal to upgrade the seismic telemetry.

2 HISTORICAL DEVELOPMENT

2.1 Prior to Y2K

A broadband seismic network featuring digital telemetry was allegedly proposed by Jurgen Neuberg, John Shepherd and Willy Aspinall within the first year of the eruption beginning in July 1995. Using on-loan equipment from the University of Puerto Rico, Richard Luckett and I made recordings using Guralp broadband seismometers between May and August 1996, and looked for evidence of volcano-seismic signals below 0.5 Hz [Thompson, 1996]. Plans to install a broadband network must have been well in place by then though as a team from BGS Seismology arrived in August 1996 to identify possible sites for installing the seismic stations. Given the desire to get the new network operational as quickly as possible, a decision had been taken to go with a system BGS Seismology had considerable experience with. The backbone of this system was the Earth Data telemetry and ILI unit, in conjunction with a VME computer running the OS9 operating system and SEISLOG acquisition and event detection software. The other key element was a Sun Sparc-5 workstation, for analysing detected events and archiving data to DDS DAT tapes.

Numerous problems were experienced with the VME and the vme_collect data archival software on the Sun workstation. By November 1999, MVO Seismologist Art Jolly was reporting that the Sun workstation was crashing quite frequently. BGS Seismology raised awareness of the Y2K non-compliance of the VME/OS9 acquisition system in early 1999, and attempted to replace it with QNX in November 1999 to no avail. Instead they patched it by installing additional electronics that would fool the VME into thinking it was 1992 by subtracting 8 years from the time code emitted by the Radiocode GPS clock.

Art Jolly made me aware of this problems also, so that I took the opportunity at AGU in December 1999, prior to even becoming MVO Seismologist, to view alternative acquistion systems being exhibited there. The most promising was VISEIS by John Rogers, a former colleague of Art's.

2.2 Problems post-Y2K

At the Y2K transition significant problems developed. The VME began crashing frequently and had to be manually restarted each time. On numerous occasions it took multiple attempts to reboot, and on one occasion it took 25 times. Levels of concern were mounting by February 2000, and it seemed these problems were not new:

From: *Dr G Norton [gill@mvomrat.com]*
Sent: *Monday, February 21, 2000 10:59 AM*

To: *'wjmc@bgs.ac.uk'*
Subject: *VME replacement*

Bill

The VME computer has crashed again, and potentially, if we cannot get it started by tomorrow (Monday) midday we will be losing valuable BB data. This is a recurrence of an old problem that the installation of the y2k fix was supposed to solve. I know that there were problems with this, and I'm not sure of the status of the fix. I've heard bits and pieces frm different people, but I think it comes down to we need the [QNX] box out here asap. Any idea what the time scale for this is? I get the feeling that MVO is a lower priority than some other jobs in GSGG, but I would like to try and get this sorted, as it is increasingly frustrating for us without a stable platform for the main monitoring tool, and is especially importent given the status of the volcano.

Also, Glenn tells me that the Sun is getting a bit flakey and is tending to crash more. What would the procedure be for getting a replacement? Is there any budget left in the y2k subhead? We would also like to get a copy of the programme MATLAB for either the Sun or one of the new PCs. At educational rates, I believe a license is about 1200 stg. Art found his very useful, and Glenn is also of the opinion that it would aid our BB processing.

...

Cheers

Gill

Not surprisingly, as MVO Seismologist I no longer had any confidence in the VME system, feeling that it could fail irreversibly at any time. We would then be entirely dependent on the analog seismic network with its VDAP system and relatively poor dynamic range, as we were prior to October 1996. However, a number of issues had also developed with the VDAP system which meant it too needed to be upgraded. Event detection was compromised, and most importantly of all, the RSAM alarm system was no longer stable. With a rapidly growing dome and frequent ash clouds and a need to alert local and aviation authorities rapidly at times, MVO was under pressure to re-establish reliable seismic monitoring. The major dome collapse on 20 March 2000 was dramatic proof of this when failures of the VME and Sun workstation caused all raw continuous seismic data to be lost. The following email shows the level of urgency felt by MVO:

From: Dr G Norton [gill@mvomrat.com]
Sent: Thursday, March 23, 2000 8:27 AM
To: 'wjmc@bgs.ac.uk'
Subject: FW: QNX needed NOW!!!

Bill
I fully endorse Glenn's comments below. Any news on likely arrival time for the QNX would be gratefuly received.
Gill

-----Original Message-----
From: Glenn Thompson [mailto:cheetah_thompson@hotmail.com]
Sent: Wednesday, March 22, 2000 6:32 PM
To: gill@mvomrat.com
Subject: QNX needed NOW!!!

Hi Bill,

Due to VME problems we have just lost 20 hours of some of the most important seismic data ever recorded, associated with the recent dome collapse, the second biggest event at Montserrat in the last 400 years! I cannot overemphasize how urgent our need is for the VME to be replaced. It is taking a ridiculous amount of time to get this essential QNX unit. BGS have been aware of problems with the VME since 1996 and these are now occuring on a daily basis resulting in frequent losses of several hours of data which seriously undermines our ability to monitor the volcano, and is a huge loss to the research community.
We need someone to configure and bring this machine out and install it within the next couple of weeks. I would really appreciate if you could put a rush on this.
We also are in great need of a new Sun workstation. This is for several reasons: (1) the present Sun has reliability problems - keeps crashing (2) the hard drives on the present Sun are too small - the drives are frequently 100% full, which means no work can be done (3) the present Sun does not have enough CPU power to do the kind of more sophisticated data processing that we wish to do. Such a machine will cost around 5000 pounds, plus we will need BGS Edinburgh to configure, deliver and install the machine for us (we do not have the expertise at MVO to do this).
Regards,
Glenn

Over the next few weeks it became clear that the QNX solution was still some way off. Meanwhile, progress on a replacement for the Sun workstation was slow as this had to be approved by DFID and their advisors. First in April we ordered a copy of PC Solaris, thinking this might be better than porting all the software to Linux. But we found PC Solaris to be a frustrating difficult operating system to install. The purchase of a PC (and a corresponding DAT drive) was not approved until August and it did not arrive until October. When it did arrive, it did not have Linux pre-installed as we had requested, and a further three months went by while we ordered Linux, and David Silcott learned how to install it.

Returning to the data acquisition - problems with the ILI/VME were increasing however, and no end was in sight. On 10 August 2000 the ILI began producing strange repetitive signals, as though it was processing the same 1s packet of data over and over. A study on

15 August revealed that there had been 16% downtime of the VME so far during the year 2000. MVO Director Gill Norton was seriously concerned and prompted Bill McCourt for an update on the QNX:

From: McCourt, William J [wjmc@bgs.ac.uk]
Sent: Friday, August 18, 2000 9:18 AM
To: 'gill@mvomrat.com'
Subject: RE: VME/QNX/whatever?

Gill

... The bottom line is that the VME replacement system is still a long way off installation at the MVO and January 2001 is not just a wild guess!!!!! I do not understand all the background to this but what I can confirm is that by the end of March all the ordered (?QNX) equipment had been delivered to E'burgh and signed off. I believe that there was a compatability problem with some of the equipment and an alternative solution was sought. This I presume is the SA24 which appears to be working but now there is a further 4 months lead time to acquire the hardware...

Cheers

Bill

-----Original Message-----

From: Dr Gill Norton [mailto:gill@mvomrat.com]
Sent: Wednesday, August 16, 2000 6:36 PM
To: wjmc@bgs.ac.uk
Subject: VME/QNX/whatever?

Bill

Sorry to keep bombarding you with messages, but here's another question - and a familiar one. Any news on the VME/QNX replacement? An interesting statistic that Glenn has just produced indicates that since the beginning of the year, the BB system has only been producing continuous data for an average of only 20 hours per day. Which means we've lost about 16% of the BB data this year - mostly as a result of VME related faults. I think this really shows the problems with system, and underlines the urgency...

This is both frustrating and also embarrassing, as the BB is supposed to be our/BGS' "flagship". I'm sure this will come out in the review, and I am definitely starting to think that we should recommend to the review team that we go for a USGS solution...

Cheers

Gill

This rather changed the equation. BGS Seismology were clearly working hard to deliver a solution, but had run into unanticipated problems with the QNX solution, and were now looking at an SA24 solution and waiting for parts. Meanwhile MVO was unable to effectively monitor a volcano which was becoming increasingly active.

2.3 The Independent Review

DFID had instructed that an Independent Review of Monitoring be held at MVO in late August 2000, and so a report [Thompson, 2000a] was written to highlight the problems with the seismic monitoring and make some recommendations.

I also summarised some of the other problems with the digital seismic network. First, its dependence on non-PC technology. Parts for Sun workstations and the VME computer were not readily available. Specialist operating systems like OS9 and even Solaris could not be supported on Montserrat. Moreover, the digital seismic network lacked real-time monitoring tools. And the data archival software was extremely unreliable and this had contributed to massive data loss from mid-1999 to mid-2000.

My preferred solution was to go with the Scream/Earthworm/Glowworm setup I had seen at the Alaska Volcano Observatory's Anchorage office while on vacation in July 2000. This was effectively the upgrade to VDAP system installed in July 1995 and still used for the analog seismic network. The Earthworm/Glowworm system was now used at all USGS volcano observatories and on VDAP responses in the developing world. Since February 2000 I had been communicating with the USGS regarding upgrading our own VDAP system. Now we were wondering if it could be a replacement for the VME too. The outstanding technical question was how could Scream/Earthworm be interfaced with the Earth Data telemetry?

Also while in Alaska I had learned more about AEIC's Iceworm/Antelope system. Interfacing this with the Earth Data telemetry was just as much of a problem, plus it carried a price tag of $30,000. So this was not an option.

The other system which needed to be evaluated was SRU's Soufriere system. Politically it would be ideal. I was able to visit in late September 2000. It had some advantages, but was firmly rooted in the DOS 6.2 technology we had experienced so many problems networking effectively with MVO's Windows NT network. Moreover, it lacked real-time visualization tools.

2.4 The MVO-BGS proposal

On my return from SRU, I summarised all the systems I had seen and made my preliminary recommendation [Thompson, 2000b]. I still viewed Earthworm/Glowworm as the most viable solution, but incorporating some of the SRU tools as add ons. I also encouraged SRU to install one of their own acquisition systems at MVO. I felt it desirable to maintain Seisan as our primary event processing system, and the Matlab tools which were rapidly being developed.

I was invited to BGS Edinburgh to discuss a way forward on 30 October 2000. It became clear that interfacing with the Earth Data ILI was the critical problem with any solution, but that experience had shown there was no quick fix to replacing the Earth Data telemetry with an alternative that could easily be interfaced to SEISLOG, Scream or Earthworm: this would take at least 18 months. Out of this came a collaborative proposal, authored by Simon Flower, Brian Baptie and myself (section 5). In the short term we would replace the VME with SA24, and somehow interface this with Earthworm. In the long run, we would replace the entire Earth Data telemetry system with something in much wider use such as Guralp digitisers and Freewave radios, and import the data into Earthworm/Glowworm using Scream.

2.5 The BGS-DFID meeting and the "turn-key" solution

On 1 December 2000, there was a meeting between BGS and DFID. Rather than let BGS handle the long-term solution, DFID felt it had to go out to international tender. DFID also decided MVO must have a turnkey system with a built in maintenance contract, so that the inadequate technical support provided by MVO technicians for the current digital network would not hamper the new network (the Independent Review of Monitoring had gone further and recommended that a ex-patriate Field Engineer to ensure adequate technical support). I did not learn of this meeting until February 2001. DFID's requirements, as minuted by Bill McCourt, are reproduced in section 3.

2.6 The interim solution

In March 2001, a team from BGS came out and installed the interim solution. The VME/Seislog system was replaced with two PCs: a Windows 98 PC running SA24, and a Windows NT PC running Earthworm. Crucially Simon Flower and David Scott had written a driver to take continuous data from SA24 and import it into Earthworm, and had also written a module to write Earthworm data out in Seisan format.

PC-SEIS was also replaced at the same time with a PC running QNX/Seislog. It was ironic that QNX, for a long time proposed as a solution for the digital network was finally utilized on the analog network. This was trivial, since there was no interfacing with the Earth Data ILI to struggle with.

With these upgrades, merging of datastreams became possible for the first time because:

- PC-SEIS could not be networked to the Windows NT server. QNX could.
- The Sun workstation could not be networked to the Windows NT server. The Linux PC could.

I wrote Perl programs to ftp data from the Earthworm and QNX PC's at regular intervals, and associate events detected on each network that fell within about 5 seconds of each other. These merged events were then fed into a picking queue. A program was also written to compute the equivalent magnitudes of these events in near-real-time, allowing Team Seismic to see if there were any particular big events waiting in the picking queue. Team Seismic would then run the Seisan program eev to process the events in the picking queue. Once classified (and located if possible) they were automatically moved to an online database and a copy was scheduled for manual backup to DDS tape.

Merging datasteams gave us several important advantages:

- event classification (& location) became more precise, as more channels were available
- there was no longer any duplicated effort (processing events on two separate systems)
- all events could be stored in the same database structure
- all events could be analysed & archived using one set of tools
- there was now less hardware & software to learn how to use, support and maintain

The upgrade from PC-SEIS to QNX/Seislog was an immediate success and never exhibited any problems. There were however recurrent problems though with SA24/Earthworm over the next few months, and for a while it did not seem they were any more reliable than the VME. However, by leaving the SA24 screen on the log page, and by setting up two Earthworm PCs in parallel (one of them acquiring all channels, the other omitting some channels known to have dropouts) these teething problems were almost entirely eliminated. The interim solution was made more robust still through the development of the diagnostic alarm system and other safety measures which improved the robustness of the seismic monitoring (OFR 02/0?).

2.7 The tendering process

The tendering process for the long-term upgrade finally got underway in (late) 2001. The organisations invited to bid are shown in section 4.

Reftek were the only interested party. They had many questions, and all technical questions had to be relayed via Bill McCourt, as direct contact between MVO and a bidder was not allowed.

Reftek's original proposal was received in September 2001. Following the closure of the tendering process (Reftek were the only interested party) and evaluation by BGS and DFID advisers Steve Sparks and Willy Aspinall, MVO was invited to comment in January 2002. The bid was costed at about £230,000 even without much of the real-time software stipulated. I worked out that we could just purchase the same equipment (including spares) and install ourselves for around £98,000. I felt that it was essential to involve MVO technicians at every stage of the tendering and installation process and rely on them for the maintenance. I felt a maintenance contract was both expensive and counter-productive. Willy Aspinall was of the same opinion. A number of other issues were also addressed in the evaluation.

Therafter MVO was allowed to interact directly with Reftek without BGS acting as a mediator. Reftek revised their bid 3 times over the next few months as the details of the equipment enclosures, telemetry system and real-time software were worked out. In August 2002, Reftek's technical offer was found to be fully acceptable to MVO. The price was £219,000 (though it would have been £120,000 more with the maintenance contract). Since August 2002, MVO has been waiting on a response from DFID. A letter from the MVO Director to DFID to this effect is included in section 6. Following numerous other requests for an update which went unanswered, BGS/MVO finally received word in January 2003 that the Reftek bid had been rejected by DFID.

The folder \\dome\seismology\documents\DAS_Tender contains all documentation and correspondence pertaining to this process (297 files).

2.8 A revised MVO proposal

Following word that the Reftek bid had been rejected, MVO was instructed to draft a new proposal. There were two clear choices: (1) either just purchase the necessary equipment proposed by Reftek, which had been thoroughly worked out, or (2) re-introduce the Guralp-based solution originally proposed in November 2000. Acting Seismologist, Lars Ottemoeller decided on the latter.

Following dialogue between Lars, Brian Baptie, Jurgen Neuberg (who was now advising the MVO Board on the issue) and myself, the proposal was finalised in May 2003 and is reproduced in section 7. It was decided that MVO would retain its LA-100 sensors at

MBWH and MBLG as these had proved to be MVO's best stations, and they were important for being able to compare future with past seismicity. It was also decided to go with the tried and trusted Freewave telemetry rather than the riskier state-of-the-art WiFi technology, though the latter seemed to offer some important benefits.

DFID finally gave their approval to this proposal in December 2003.

2.9 Conclusion

There were three distinct stages to the upgrade of MVO' seismic monitoring programme:

- The first and easiest stage was to upgrade MVO's data analysis, alarm and archival systems. The main problem had been the unstable nature of the Sun workstation, its old DAT drives, the poor data archival software, and the lack of an alarm system and analysis software. These upgrades were achieved at MVO mainly through a substantial effort to develop new Perl and Matlab programs, and the purchase and configuration of a Linux PC.
- The second stage was to upgrade the data acquisition systems. The extreme unreliability of the VME and problems with the VDAP system following Y2K made it imperative to upgrade MVO's acquisition systems. This upgrade was not something MVO was positioned to achieve without considerable support from BGS, who were the experts with the Earth Data telemetry system and VME. The upgrade was considerably delayed to due to difficulties BGS Seismology had in finding anything other than the VME that could interface with the Earth Data ILI unit, and was eventually delivered in March 2001. Teething problems were resolved by MVO.
- The final and most difficult stage was to upgrade to seismic networks. Concerns surrounding the obsolete nature and likely lack of future support available for the Earth Data telemetry were crucial in the decision to seek a long-term solution that would eliminate them. Presentation of a joint MVO/BGS proposal in November 2000 led to a decision by DFID to initiate an international tendering process to procure a turn-key system, which was somewhat of a surprise to MVO when made aware of it in February 2001. The tendering process concluded with DFID's rejection of Reftek's bid in January 2003, having effectively caused a 2 year delay.

  In May 2003 a revised version of the original MVO proposal was submitted to the MVO Board and approved by DFID in December 2003. It is anticipated that equipment will be ordered soon and will be available on the island within the next 12 months.

The MVO is indebted to BGS Seismology (particularly Brian Baptie and Simon Flower) for the support they provided at each stage.

3 DFID-BGS MEETING RE: MVO 01/12/2000

Present: Dr David Falvey BGS (Chair), Prof. Steve Sparks, Dr Willy Aspinall, Mr Rod Matthews (DFID), Mr Alan Campbell (DFID); Dr C. Browitt, Mr D. Ovadia, Dr W. McCourt, (BGS) and Dr B. Baptie & Mr S. Flower (BGS, by video link).

The main purpose of this meeting, which was requested and organised by BGS International, was to consider various issues of equipment and staffing relating to the upgrading of the seismic data logging/acquisition systems at the MVO arising from an internal technical meeting held at BGS Edinburgh on the 31/10/00. A brief summary statement and relevant background was provided by WJMc, following "around the table" introductions.

Mr Matthews set the scene by establishing an agreed process for the meeting as follows: "The MVO has certain needs/requirements that have to be addressed with some urgency. Their present data acquisition system (DAS) is unreliable and needs to be replaced and this meeting is charged with addressing that problem and finding the right solution to be made available in the correct manner and (right) time frame"…… The idea is to move away from a series of contracts with different suppliers and instead identify a single vendor to provide a total service provision to the MVO.

In the first instance the customer (MVO) needs and requirements have to be established which have to be written into a proper functional "spec" for discussion at the MVO Board meeting in January. Following approval by the board, an invitation to tender will be issued to potential suppliers who will submit their technical and financial response (bids) for evaluation by a technical panel appointed by DFID.

B. Baptie/S. Flower commented that many of the companies involved are strictly supply companies and would not be able to meet the strict requirements of maintenance and back-up that is fundamental to the process at the MVO. What is required is an organisation that has sufficient expertise and knowledge to fully support the volcano monitoring programme along with appropriate technical support of the instrumentation, …in other words a complete service provider with proven volcano-seismic experience and demonstrated track record not simply hardware contractors and/or suppliers of equipment. *"These are few and far between in our experience".*

It was accepted by the meeting that the correct way forward was to have the technical and scientific expertise on the Island, at the MVO, and a call-down total support contract in place with the suppliers/operators to meet the requirements of the MVO as defined by its Director in consultation with the resident seismologist.

D. Ovadia clarified the roles and responsibilities involved: MVO is the customer, DFID the funder and organisations such as BGS the contractor/supplier.

It was accepted that the upcoming MVO Board meeting provisionally set for January (18^{th}) was the correct scenario to discuss these procedures and McCourt, in consultation with the MVO Director and Seismologist, was charged with producing a "functional requirement proposal" for discussion. This document has to be available to the MVO Board members for consultation prior to the meeting and it was agreed that it would be provided as a draft one week before the meeting. McCourt had responsibility to project manage the process and ensure no conflict of interest and that a full transparent audit trail was properly in place.

At this juncture Dr Aspinall introduced the question of the role of the MVO in relation to aircraft safety and the need to define the role of the MVO and its scientists in this area. Presently it is rather an *ad hoc* arrangement with the MVO informing ATC on Antigua, the States (NOAA) by fax or phone of the presence of an ash-cloud above 10,000 feet. In times of poor visibility and/or at night this is dependent on an effective alarm system tied into the seismic monitoring network, however, if the seismic network is down for any reason then the alarm will not function

Dr Peter Dunkley, who was acting Director MVO from Sept-Nov. was called into the meeting to give further details of the procedures in place at the MVO and satisfied the meeting that the Observatory was responding in the correct way; however, the GoM/MVO Board/?DFID have to make the decision as to whether the MVO scientists have a responsibility in this area and if yes ensure that the proper arrangements are in place. Prof. Sparks stated that the responsibility of the MVO in this issue, if accepted by the Board, would need to be included in their mission statement

In terms of the time-scale involved for upgrading the seismic DAS at the MVO, there is a need for an immediate emergency response to the problem plus a longer-term programme of substantive replacement ideally to coincide with the move to the new MVO at Fleming's planned for late 2001 (?October). The immediate response involves reinforcement of the current network and replacement of the defective parts. The preferred solution is that provided in the BGS "MVO Concept Paper" involving an immediate technical visit of about 2 weeks in Jan-Feb for upgrade of the short-period and broadband networks and routine maintenance/trouble-shooting visits over the next 9-12 months by BGS staff. It was stressed by Mr Matthews that any solution to the DAS problem has to be reached in consultation with the MVO Director and seismologist and they have to be happy with any proposal.

- S. Flower and McCourt were charged with the responsibility for organizing this "quick-fix" solution in consultation with the MVO Director and Seismologist. Costs had to be provided a.s.a.p. to DFID through Mr Campbell, who would be in Montserrat from the 10th, in order that appropriate level of funding required could be quickly be established.

A further point of discussion was the potential need for a (?full-time) instrumentation technician/engineer at the MVO to work with the resident seismologist and thus allow him more time for data interpretation and evaluation rather than technical maintenance of the equipment. This is a complicated issue involving as it does local staffing and the regional role of the MVO and its relationship with other volcano observatories/seismic units and requires a fuller discussion by the MVO Board. It was agreed however that there was a need for such expert back-up and BGS were through Mr Flower were asked to provide a solution by the meeting. The proposed BGS short-term solution is to send an experienced instrumentation technician to the MVO in February for about 30 days, either with or following on from the above Jan/Feb visit to ensure that any "teething problems" of the new systems are addressed, to undertake routine maintenance and to instruct the resident electronic technical staff at the MVO in trouble-shooting procedures. This visit in conjunction with the scheduled visits over the 9-12 months before the move to the new MVO fully addresses the problem and should be sufficient to ensure smooth running of the networks up to and during the move to Fleming's by which time the longer-term problem of a (resident?) instrumentation engineer has to be resolved.

Returning to the specifications for the "longer-term" solution the Chair expressed the opinion that it must be clearly and unambiguously stated in the documentation that this is a total service provision contract to include supply of hardware and logistical and technical back-up including regular maintenance checks and unscheduled emergency call-down arrangements. It was also commented by Mr Campbell that eventually the volcano monitoring services would have to be "localised" in Montserrat and paid for by the GoM and thus the long-term sustainability of the system(s) was an important factor along with technical merit, price, performance etc.

Mr Matthews commented that such factors had to be taken into consideration by the technical panel who would evaluate the bids, such a panel could comprise the two DFID scientific consultants (S. Sparks, W. Aspinall), most probably the DFID adviser and an external seismologist. Reference to the panel must be included in the concept paper to the board to be prepared by McCourt.

Returning to the issue of aircraft safety Mr Aspinall made the recommendation that the MVO should keep a record, preferably a recording, of phone calls made to ATC and other agencies (NOAA) "just in case"; in addition both the fax and call were dependent on the availability of a land line that could fail in the event of an eruption. It was established from Dr Dunkley that there was a satellite phone at the MVO and the need to have it tested regularly and ensure it was in working order was to be included in the H & S he was in the process of compiling for the MVO. The H & S file was initiated on the order of Dr Falvey following a September visit to the MVO. Dr Dunkley also confirmed that if for any reason the MVO had not contacted NOAA in any 7 day period this produced a periodic check by NOAA of the actual situation at the SHV and its impact on aircraft safety. It was again stressed that records should be kept of all such conversations.

Reference was made by Prof. Sparks to the MVO Risk Assessment Meeting, suggested dates were the 16-17th January 2001 with the MVO Board to meet on the 18th. These dates had been discussed with HE the Governor and an action was placed with Mr Campbell to confirm the dates of the RA Meeting during his upcoming visit to Montserrat.

Dr Aspinall returned to the subject of an instrumentation engineer/technician at the MVO and its wider implications for local staff at the MVO. Prof Sparks added that the presence of a such an individual would be critical in the transition period from the present observatory to the new one. It was agreed in open discussion that there almost certainly was no-one on Island outside of the MVO who could fill the post nor was it feasible in the longer term to train up one of the present staff since this would create an in-balance in the present delicate local staffing arrangements at the MVO, all of whom were GoM employees with determined grades and job descriptions etc. Although it was recognised that this was a local management issue Baptie and Flower both endorsed the need to have a dedicated technician on the ground and possibly the answer was to outsource the post regionally or establish a service level agreement with the other Observatories in the area all of whom employ such qualified technical people, for example, the French run observatories on Martinique and Guadeloupe.

- An action was placed on BGS, (Flower-)McCourt, to liase with Director MVO to produce ToR's/job description for such a technician (?)for consideration at the MVO board meeting in January. (The immediate technical needs are to be addressed in the BGS Phase I action plan for the upgrade of the DSA at the MVO).

As a concluding remark to the meeting Mr Matthews confirmed that the first point of contact at DFID for MVO related matters was Mr Alan Campbell, although the responsibility for the MVO lies with the Governor's office on Island. Mr Ovadia stated that Dr McCourt was the BGS Project Manager for the MVO and thus the first point of contact with BGS.

4 ORGANISATIONS INVITED TO BID

Invitations to tender issued 15 May 2001:

1: Lennartz Electronic GmbH
Bismarckstrasse 136
D-72072 Tubingen
Germany.

2: Dr John Shepherd
Seismic Research Unit
University of the West Indies
St Augustine
Trinidad and Tobago
West Indies

3: Dr W. Aspinall
Aspinall and Associates
5 Woodside Close
Beaconsfield
Bucks
HP9 1 JQ

4: Simon Fowler
British Geological Survey
Murchison House
West Mains Road
Edinburgh
EH9 3LA

5: Nathan Pearce
Gurlap Systems Ltd
3 Midas House
Calleva Park
Aldermaston
Reading
RG7 8EA

6: Kinemetrics Inc.
222 Vista Avenue
Pasadena, CA91107
USA

7: Earth Data Ltd
Nutsey Lane
Totton
Southampton
SO40 3NB

8: Refraction Technologies Inc
2626 Lombardy Ln
#105 Dallas
TX 75220
USA.

9: C. Daniel Miller
Cascades Volcano Observatory
US Geological Survey
5400 MacArthur Blvd
Vancouver
WA 98661

10: Steve McNutt
Alaska Volcano Observatory
U.S. Geological Survey
Geophysical Institute
University of Alaska
Fairbanks
AK, 99775-7320

11: U.S. Geological Survey
345 Middlefield Road
Menlo Park
CA, 94025
USA

12: Dr J. C. Komorowski
IGP
c/o Observatoire Volcanologique de la Soufriere de Guadeloupe.
Le Houelmount
97113 Gourbeyre
Guadeloupe French WI.

5 THE FUNCTIONAL SPECIFICATION FOR THE NEW DIGITAL SEISMIC NETWORK

5.1 Introduction

1 The Natural Environment Research Council (NERC) is a body funded by the Office of Science and Technology, and is responsible for research in the environmental sciences. Apart from work undertaken by its own staff, NERC also supports environmental research within universities and other higher education institutes by awarding grants, and through cooperative projects.

2 NERC comprises a number of research centres and surveys at sites throughout the UK. These range from the largest with about 500 staff to the smallest with 10 or less staff. There are over 20 sites with a total staff of approximately 2,300. The British Geological Survey (BGS) is one of the component bodies of NERC, and has its headquarters at Keyworth in Nottinghamshire. There is a second major site at Edinburgh, and further, smaller presences at other locations.

3 The former International Division of BGS, now BGS International®, is responsible for seconding scientific staff to the Montserrat Volcano Observatory (MVO) and the supply of certain equipment, under the terms of a contract let by the Department for International Development (DFID). The MVO, which in this case is formally the client, is a statutory body under the Government of Montserrat and is controlled by a Board co-chaired by the Governor of Montserrat and the Chief Minister of Montserrat on which the Director of the MVO, who is a senior BGS staff member, has a place.

4 This procurement is being handled by BGS International on behalf of the MVO according to standard NERC/BGS procurement rules which are broadly those of the UK Civil Service. Any contract resulting from this Invitation to Tender (ITT) will be placed by NERC/BGS and funded by a subvention from DFID.

5.2 Background

5 A functional seismograph network is an essential part of routine monitoring and surveillance of a volcanic eruption. Seismic monitoring is by far the most important technique for monitoring volcanic activity because:

- Almost every volcanic process has a characteristic seismic signal. No other technique is nearly so versatile.
- Seismic monitoring is the only technique that gathers real-time data, 24-hours-a-day.
- Unlike visual observations, seismics can "see through" cloud, which covers the volcano almost all the time.

6 When compared with other monitoring techniques such as GPS and gas monitoring, seismic monitoring provides excellent value for money. A seismic station is relatively cheap compared to the alternatives, the amount of helicopter support required is less, and the data returned of more value. Whilst seismic monitoring alone is not an effective way to monitor an active volcano, it is the only indispensable technique.

7 The Montserrat Volcano Observatory (MVO) currently has two separate seismic acquisition systems. The short period network, which was installed before the present volcanic crisis, is based on short period sensors, analog radio transmission and MS-DOS based data logging. The broadband network, installed to help monitor the present crisis, uses broadband sensors, digital radio transmission and VME/OS-9 based data logging.

8 Various problems currently affect the operation of both the seismic networks on Montserrat. An interim plan has been proposed by the British Geological Survey Seismology Programme that will correct some of these problems in the short term and provide workable contingency plans in the event of a failure of critical seismic equipment. However some major changes to the seismic monitoring network will still be needed after these short-term plans have been implemented.

5.3 The case for an upgrade

9 The Interpolating Line Interface (ILI) which was installed as part of the original broadband network is nearing the end of its useful life and is proving difficult to maintain. The broadband network cannot operate without this item. Since the radio links and digitisers that are used for each seismic channel are only compatible with the ILI, replacement of the ILI implies replacement of these items as well.

10 On completion of the interim plan, the broadband data will be delivered in a more reliable way, but a time delay in delivering the data will have been introduced. To ensure timely analysis the broadband data logging system must be replaced.

11 A preferred solution is that the short period and broadband networks are merged. This would remove the overhead of duplicate maintenance for the dual set of outstations. It would also remove a considerable workload from the staff at MVO who are required to merge data from the two networks manually before making an analysis.

12 Although the interim plan provides for the replacement of many of the older items of equipment, some important items, such as the modulators and demodulators used in the short-period network, will not be replaced under this plan. These items are now very difficult to maintain and their failure would result in the failure of the entire short-period network.

5.4 Functional Specification For A New Seismic Monitoring Facility

13 This specification describes a single seismograph network consisting of both short-period and broadband sensors. This new network will unify the current short-period and broadband networks and use many of the existing seismometer locations. There is no advantage to be gained by replacing the existing seismometers in the broadband network and these are to be retained. However the seismometers from the short-period network are now passed their useful life and will not be re-used.

5.5 Part 1 – Outstation Network

14 The new seismic network will have a minimum of five 3 component, broadband sensors whose amplitude response is flat to velocity in the range of 30s to 100Hz or greater. These instruments will be supplemented by sufficient single vertical component sensors to achieve optimal event discrimination and hypocentral location and give sufficient data redundancy in event of failure due to hardware malfunction or volcanic activity. The required redundancy is that the network should be able to tolerate the loss of at least a single station without loss of capability.

15 The outstations will comprise a single homogeneous network that can easily be extended if required. Infrastructure for many of the existing sites can be used though some new sites may be required to improve azimuthal coverage and for radio telemetry reasons. Where new outstations are required the supplier must include in their quote all costs associated with creating the new outstation, including digging and consolidating the seismic pit, housing the electronics and installing a solar-based power supply.

16 Data from all sensors will be digitized and time stamped by a GPS synchronized clock with accuracy better than ±1 millisecond. Preferably this clock should be centrally located (at the observatory) and the time distributed through the radio network to the outstations. This ensures high relative time accuracy and therefore good location

capability even at times when the GPS signal is unavailable. If the supplier is unable to provide this method of distributing time data and intends to use GPS receivers at each outstation, then they must quote the worst case clock drift at times when the GPS receiver is not synchronized with the GPS satellite system.

17 Continuous data will be transmitted to the observatory by radio telemetry for subsequent analyses. The overall dynamic range of the system will be in excess of 120dB to allow accurate determination of amplitudes over several magnitudes. The sampling rate will be a minimum of 100Hz to achieve a suitable timing accuracy for event location. Duplex radio communications should be used since they allow remote state of health checks and retransmission of missing data blocks. Auxiliary channels for additional monitoring parameters with lower data rate are a desirable feature.

18 Where new sites are required they will have robust construction bearing in mind the environment of ash, flooding and hurricanes. They must incorporate lightning protection devices. Also they must incorporate a degree of thermal insulation to improve noise performance. The latter can be achieved by burial to a depth of a least 1m. Solar panels and 12V batteries will supply outstation power. Falling ash often partially obscures solar panels, so it may be prudent for the supplier to over specify the generating capacity of their equipment.

19 Due to the irregularity of the volcanic terrain, direct line-of-sight communications between individual sites and the central observatory cannot be guaranteed. In such cases, repeater sites will be required to relay the data back to the observatory. It is essential that the repeater sites are accessible and not in remote locations, which can only be accessed by helicopter.

20 Once the system has been installed the supplier will make a full system calibration and provide response data for the entire network.

5.6 Part 2 – Analysis System

21 The essential features of the data analysis system are near real-time seismograms and spectrograms for all channels along with the graphical display of real-time seismic amplitudes, averaged over a period of minutes, on the users selection of channels. In addition, the system should support helicorder output for multiple channels. An easily tunable, multi-channel detection algorithm will provide triggered event data that can be subsequently examined by seismic analysts. A data archival facility will allow archival of both triggered events and continuous data from selected channels on to robust media for long-term storage. For reasons of backward compatibility the data output format must be compatible with the Seisan data format and the data logging system must interface to the existing Seisan installation.

22 Since the observatory will not be staffed 24 hours per day, an alarm system will be required. The system will incorporate both trigger and amplitude information with the ability to call pager numbers for key personnel. Also required is the ability to remotely

interrogate the monitoring system in near real-time to assist with response to alarms. All data analysis and acquisition hardware should be PC-based and therefore readily replaceable at short notice.

23 In addition to the above, it is highly desirable, though not essential, that the system will automatically restart in the event of a system failure, without user intervention. The entire system must have the capacity for expansion (i.e. the adding of new seismic or other data channels) and it must be possible for MVO staff to perform such reconfiguration operations.

5.7 Existing equipment

24 The following equipment already exists or is expected to exist at the time of the installation of the new facilities. If the supplier intends to use any or all of this equipment in his proposal, he must describe fully how this will be incorporated and confirm that all existing equipment incorporated into the new facility will be absorbed into the maintenance agreement.

25 Currently deployed on the broadband network are four Guralp CMG-40T, broadband, three component seismometers, one Integra 3JLA-10, three component seismometer and three Integra LA-100 vertical component seismometers. There are also 4 spare Integra LA-100 vertical component seismometers. Since these seismometers are to be re-used in the new network the supplier must be able to interface their equipment to them.

26 Existing digitizers are not suitable for re-use as they do not support local time stamping of data. Also, existing digital radios are unsuitable as they can only be used in conjunction with existing digitizer output. However, other outstation equipment such as antennae, masts, clamps, solar panels, regulators, lightening protectors, cabling and batteries, essential for any installation, are available. Reasonable levels of spares for these items also exist, however the existing solar panel/battery power supplies were only designed to supply 2.5W. Suppliers will need to provide additional solar based power supply if the consumption of their equipment exceeds this amount. In any case they must ensure that adequate power is available to supply their equipment.

5.8 Installation, Spares and Maintenance

27 The supplier will be expected to deliver all components of the equipment proposed to the MVO in Montserrat and to install these as appropriate and on the advice of the technical staff of the MVO. For the purposes of planning installation, the supplier may assume that normal office / laboratory facilities (i.e. clean power supplies, benching, cable trays etc) are available at the MVO and that the technical staff there will make and fund all reasonable and pre-agreed arrangements for logistical support (helicopter time etc) for the installation of field equipment. A full training and hand-over package should be included together with details of acceptance criteria to be used.

28 A minimum of an additional 50% of all outstation hardware should be held as spares at MVO. Since this level of spare seismometers are not currently available the supplier must contact MVO to determine the level of spares and include a costing for new seismometers to bring the level up to at least 50%. Also, there must be a single complete spare analysis system, pre-configured, that can be used in the event of a catastrophic failure of the analysis system.

29 The supplier must also offer a maintenance and support package, for a minimum period of three years following hand-over and acceptance, as a separately identified and costed but integral part of the proposal. The supplier must define the response time for restoring the system to normal operation and give details of how this will be achieved. The supplier will provide the following information on the maintenance staff: their level of competence, their location and if they are directly employed or sub-contracted. The proposed location of the spares for the system must also be given. The supplier must describe his fault escalation procedures and should propose a system in which penalty clauses apply against the supplier when contracted repairs times are not met. A sample of the maintenance agreement should be included in the proposal.

6 LETTER FROM PETER DUNKLEY TO DFID

Mr. Tim Hatton
Overseas territories Department
Department for International Development
1 Palace Street
LONDON SW1E 5HE

MVO/421

18 September 2002

Dear Tim

Upgrade of digital seismic network

Further to my letter of 18th August, I am writing with some concern regarding the lack of progress with the proposed upgrade to the broadband seismic network at the MVO.

I will not go into the history of the proposed upgrade and tendering process, which has evolved over the past two years, since DFID has been involved with each stage of this. I understood, however, that DFID had agreed at a meeting with BGS in late March that the network still needed to be upgraded, and implied that funding would be made available for this outside of their contract. I was also under instruction from DFID to write to you in person when all the technical aspects of the upgrade had been agreed between Refraction Technology Inc. and the MVO. This I did in my letter of the 18th August. I am therefore concerned and somewhat confused to have received an e-mail message yesterday from

Catherine Ablitt-Jones, informing me that you are now unable to authorise expenditure on this project.

As Director of the MVO, I believe it is very important that other parties with a responsibility for the MVO have a clear understanding of the need for the upgrade and the implications should this not be implemented. I am therefore copying this letter to several other stakeholders.

The broadband system underpins the MVO's monitoring of the volcano. It is fundamental to our alarm system, and during escalating volcanic eruptions is the only practical monitoring tool; except for visual observations, which are often not possible during such events. The acquisition system of the broadband network has been ailing for some time, although temporary measures were implemented by BGS in March 2001 to ensure that it continued to function until the proposed comprehensive upgrade could be carried out. At the time, BGS guaranteed that the interim solution would suffice for a period of 18 months. We have now passed the 18 months mark, and can no longer guarantee that the system will continue to operate. From time to time it fails, and staff have to be constantly ready on a 24 hours basis to take emergency measures, which is both frustrating and tedious. Apart from failures at night, when the observatory is not staffed, I am also extremely concerned that we could experience a terminal failure of a crucial component, which would render the entire system useless, and leave the MVO with only a very basic short period analogue seismic monitoring network.

Through its contract with DFID, BGS has agreed to continue managing the MVO until March of next year. However, this was partly on the understanding that the broadband seismic system would be upgraded, ideally at the time of the move to the new observatory. With this in mind, BGS submitted indicative costs to DFID in its financial proposal for additional staffing related to the installation of the new (Reftek) broadband system. I am therefore concerned by what appears to be a change of commitment by DFID.

As Director of the MVO, I can no longer guarantee that we can keep the broadband system operating. Obviously we will do whatever we can to shore up the system; although this is not the way to monitor such an active and potentially dangerous eruption, which shows no sign of abating and could continue for many years. BGS will have its corporate view on this issue and no doubt will be contacting you in due course; but from a personal point of view, I have serious misgivings, finding myself in such a responsible position with respect to the safety of the population, but at the same time knowing that crucial monitoring systems are not sufficiently reliable and could fail completely, without warning.

A great deal of time and public expense has been spent on the planning and tendering process, which I hope will not have been in vain. I am obviously not privy to the negotiations between DFID and GoM, but I must stress that I can no longer afford the time to continue to be pushed and pulled between the two organizations and given evasive answers on this issue. Whilst I may be confused by aspects of the present situation relating to future funding, I am under no illusion that the volcano is in a very active and potentially dangerous state, and unless the planned upgrade is implemented we will find ourselves, sooner or later, with very inferior seismic monitoring, which will be inadequate for the level of risk that the Authorities have to manage. I therefore sincerely hope that funding can be found so that the system can be upgraded as a matter of urgency.

Yours sincerely

Peter Dunkley
Director

cc. HE Anthony Longrigg
Mrs. Angela Greenaway, Development Unit
Dr. Bill McCourt, BGS

7 MVO PROPOSAL FOR A PROJECT TO UPGRADE THE SEISMIC NETWORK (MAY 2003)

7.1 Introduction

A functional seismograph network is essential for the routine monitoring and surveillance of an active volcano. Seismic monitoring is not affected by changes in weather conditions and provides data 24 hours per day. Especially at times of cloud cover, seismic data gives the only direct method of monitoring volcanic activity. Almost every volcanic process has a characteristic seismic signal, which means that ongoing physical processes in the volcano can be understood from the seismic data. In addition seismic monitoring is more cost-effective than other monitoring techniques. The volcanic alarm system that is critical to the safety of the population of Montserrat and aviation in the region requires the uninterrupted operation of the seismic network.

Since the seismic network is the key tool for monitoring volcanic activity, robustness and reliability in the operation of the network are essential. The systems that are in use at the MVO at present do not fulfil these criteria, and for technical reasons are expected to become increasingly less reliable in the near future. This would severely hinder the operation of the MVO and its ability to provide timely warnings of escalating activity. Therefore, it is necessary to upgrade the seismic network.

A review of monitoring strategy was commissioned by DFID in August 2000, and recommended that the MVO's digital seismic acquisition system should be upgraded. BGS implemented an interim solution in early 2001 in order to keep the system running for a further 18 months, whilst a more permanent upgrade was implemented. Following a protracted tendering and negotiation process, the MVO submitted a final technical and financial proposal to DFID in August 2002, for the upgrade of the system to be implemented by Refraction Technology Inc (RefTek). DFID has recently let it be known that funding is no longer available, and that the Government of Montserrat should finance any upgrade. In response to this, the MVO has prepared the following proposal for upgrading the system. If accepted, the upgrade will be implemented by MVO with some external support. The total cost of the proposed upgrade is approximately £122,000, as compared with the RefTek proposal, which would have cost approximately £240,000 (although that figure included additional support and software development). There is some urgency in undertaking this work, given that the BGS interim (18 month) solution was undertaken two years ago, and the system can no longer be guaranteed to continue functioning.

7.2 Currently operating seismic networks

The Montserrat Volcano Observatory currently has two separate seismic acquisition systems. The analog network, which was installed at the beginning of the eruption, is based on short period sensors and analog radio transmission. The digital network, installed at a later stage, uses broadband and short-period sensors and digital radio transmission. The data from both networks are acquired and stored by PC systems.

The numbers of stations deployed at present are 6 for the analog network and 8 for the digital network. Four of the stations are presently co-located at the same sites, which means that 10 independent sites are in operation. Due to limitations of the bandwidth with the digital radios used in the digital network, no more stations can be added to the existing digital acquisition system. Thus, the plan for merging the two networks into one cannot be realized with the current radio telemetry set-up. For both systems it is becoming increasingly difficult to replace parts in case of malfunction. The interim solution carried out by BGS in 2001 was meant to alleviate problems with the data acquisition for an 18 months period until the new system would be installed. This period is over, and reliable operation of the existing system can no longer be guaranteed.

7.3 Description of the operation of the proposed new seismic network

Under this proposed plan, both the digital and analog seismic networks will be integrated into one digital system, consisting of seismic sensors, digital telemetry and data acquisition system. The only equipment from the existing system that can be used in the new network are the seismic sensors and parts of the pit infrastructure at the field sites. Both the analog and digital acquisition systems that are presently used will be removed. At the field sites, new 24-bit digitisers with a GPS receiver will be installed. Each digitiser will send time-stamped data, which will be transmitted to the central recording station at the MVO by digital spread spectrum radios. For some of the transmission links, radio repeater stations will be required.

An important constraint is that any new system be compatible with the USGS's EarthWorm system. This software has been used at MVO since March 2001 for recording continuous data and triggering event data, and is used at many volcano and seismological observatories worldwide. Incompatibility with EarthWorm would have repercussions throughout all MVO's seismic data analysis, alarm and archival systems which could take several months to resolve, and result in staff having to be retrained to use new software.

The main benefits for merging the two networks are:

- High quality (large dynamic range) data will be obtained from all stations
- Ability to accurately classify and locate events will be improved
- Spare parts will only be required for one system
- Reduction in workload, since only network and data acquisition system will have to be maintained
- Future stations can easily be integrated

For redundancy it is suggested to install two central recording systems, of which one is active at a time, but the respective other system can be activated upon failure.

7.4 Description of technical details of the new network

Stations and sensors

The new digital network will consist of 10 seismic stations (8 existing digital network sites, plus 2 additional sites from the analog network):

Station code	**Station name**	**Sensor installed at present**	**Sensor to be used in new network**
GB	Garibaldi Hill	CMG-40T	CMG-40T
GH	St. George's Hill	CMG-40T	CMG-40T

BY (or SE)	Broderick's Yard (might be moved to Spring Estate)	none	CMG-40T
WH	Windy Hill	LA-100	LA-100 (reference station)
LG	Long Ground	LA-100	LA-100
RY	Roche's Yard	CMG-40T	CMG-40T
SS	South Soufriere	LA-100	L4
RV	Rendezvous Village	LA-100	L4
JH	Jackboy Hill	L4	L4
LY	Lee's yard	other unknown	CMG-40T

MVO presently owns a mixture of working sensors in following quantities:

Guralp CMG-40T	x 5
Integra LA-100	x 7
Integra 3JLA-10	x 1
Sercel (formely Mark Products) L4	x 5
Other unknown (Sprengnether, Dyneer, …)	x 3

Due to technical advantages, MVO would prefer to use CMG-40T sensors, followed by Sercel L4-C, followed by Integra LA-100. Other sensors would become obsolete. For long-term data consistency reasons, MVO would want to have at least a 25% level of spares for each sensor type. The table provided above is based on these considerations. Two additional CMG-40T sensors will have to be purchased in order to fulfil the minimum 25% level of spares requirement.

Modification to some of the existing seismic site infrastructure will be required. The power consumption with the new equipment will be higher than for the existing network, which will require additional solar panels and batteries. For the L4 and LA-100 sensors new interfacing with the CMG-DM24 will be required. The dimensions of the CMG-DM24 are larger than existing equipment, and therefore changes to the pits in the field, which currently house the stations, will probably be required. Additional power will also be required at repeater sites, though since most repeater sites run off mains power, this is largely a matter of increasing backup power.

Digitisers

All sites will be equipped with the Guralp 24-bit digitiser CMG-DM24. The digitiser has a dynamic range in excess of 120 dB. The digitiser sends data in form of RS232 and supports retransmission, which is an essential requirement. Data will be sampled at 100 Hz.

Data transmission

The MVO has developed considerable experience and technical expertise with the radio equipment provided by Freewave Technologies. These spread-spectrum type radios are already deployed extensively in the continuous GPS network, the remote gas-monitoring network, the remote digital camera network, and for the transmission of data from a remote weather station. Spread-spectrum duplex radio transmission is expected to sharply reduce telemetry drop-outs and interference. Therefore it is recommended that Freewave radio equipment should also be used for the seismic network. The Freewave radios provide error free transmission at 115,200 baud, which is fully sufficient. Some of the remote sites do not have direct line-of-sight with the MVO and repeaters will be required. The point-to-point link with Freewave radios can have no more than 2 repeaters. At present, the repeater sites used by the MVO seismic network are Silver Hills (RSI), Jackboy Hill (RJH), Olveston (ROL), Garibaldi Hill (RGB). An additional repeater is planned at South Soufriere Hills (RSS), whilst RJH should become obsolete.

The numbers of spread spectrum radios required per link are given in the following table (the numbers of radios are listed per link, for the site and repeaters):

Site	Number of radios	Repeater sites
SS	5	RSS-RGB-
BY (or SE)	2	RGB-

RY	5	RSI-ROL-
LG	5	RSI-ROL-
GH	1	-
WH	1	-
GB	1	-
RV	3	ROL-
JH	5	RSI-ROL-
LY	1	-
TOTAL = 29 + 5 at MVO = 34		

Generally one radio is required per station, plus radios at the repeater sites, which gives the total number per site. It may be necessary to have two radios per repeater site, which is why the number of radios per repeater site in the links with two repeaters is doubled. At the MVO, 5 radios will operate in grandmaster mode, which means one receiver is used for more than one radio link.

Data acquisition

Guralp delivers the Scream data acquisition software with the digitisers free of charge. The software supports a total of at least 99 channels. An existing Scream to Earthworm module used by the MVO will continuously feed the data into Earthworm, thereby satisfying the compatibility requirement stated earlier.

Helicorder plots

The MVO presently operates a number of drum recorders, which are an important tool for the real time monitoring. To keep this option, a digital to analog data converter (DAC) will be required to feed data into the drum recorders. A spare DAC will be required, since failure of this DAC would otherwise mean that MVO’s real-time monitoring operations are severely undermined.

Computer equipment

Two PC server machines will be required (one as a spare). The computers will be equipped with multi serial ports.

Spare parts

A reasonable number of spares (more than 25%) for all equipment should be included, and is budgeted for where not already available.

7.5 Installation

The MVO's technical staff will install the equipment. At the time of installation support from an additional seismologist (or field engineer) may be required.

7.6 Case for single tender action

The MVO presently has five CMG-40T broadband sensors manufactured by Guralp Systems Ltd. Two more of these sensors will need to be purchased. The Guralp digitisers provide the most compatible interface to the sensors produced by the same company. The Scream software provided by Guralp allows remote control of digitiser and sensor, which means that generally fewer visits to the sites will be required for maintenance. It is therefore strongly recommended that the upgrade of the seismic network be based on Guralp equipment.

There are few companies that could possibly provide the seismic equipment required for the proposed upgrade. Guralp equipment has a good reputation and is generally considerably cheaper than that offered by other companies. For example, the price for a 3 channel 24-bit digitiser from Guralp is 1600 GBP, while it is 4000 GBP for the equivalent unit produced by Refraction Technology Inc (RefTek). Considering the significant difference in the cost, it appears that Guralp offers better value for the money. However, the main argument for single tender action is that technical compatibility with existing sensors can best be achieved with Guralp digitisers. In preparing this proposal, quotations were obtained from RefTek, but the equivalent equipment would cost approximately £30,000 more than that marketed by Guralp.

For reasons of compatibility and experience at the MVO it is suggested that the telemetry should be based on Freewave digital radios. Guralp are experienced in building seismic networks based on their sensors and digitisers used in conjunction with Freewave radios.

7.7 Costs

The cost of this proposal is estimated to just over £112,000 as detailed below:

	Product	quantity	unit price	price
Data Acquisition				
Guralp	CMG-40T sensor	2	£4,000.00	£8,000.00
	CMG-DM24 digitizer, 3channels, CMG-GPS2	13	£1,600.00	£20,800.00
	Cables	13	£120.00	£1,560.00
	Scream software	1	£0.00	£0.00
	Helicorder output	2	£500.00	£1,000.00
			subtotal	**£31,360.00**
Field Misc (seismic stations)	(solar panels, batteries, lightning protection, container box, connectors, cables, regulators)	12	£1,200.00	**£14,400.00**
Dell	Computer and backup	2	£2,000.00	**£4,000.00**
	Multi serial ports	2	£250.00	**£500.00**
Data Transmission				
	Repeater site infrastructure	2	£1,000.00	£2,000.00
Freewave Technologies	FreeWave SpreadSpectrum radios at MVO	5	£800.00	£4,000.00
Freewave Technologies	FreeWave SpreadSpectrum radios in field	29	£800.00	£23,200.00
Freewave Technologies	FreeWave SpreadSpectrum radios spare	9	£800.00	£7,200.00
	antenna + cabling	43	£120.00	£5,160.00
			subtotal	**£41,560.00**
Specialist Support to MVO Seismic Team				
	staff time	20	£422.00	£8,440.00
	subsistence	20	£43.00	£860.00
	travel	1	£1,127.00	£1,127.00
			subtotal	**£10,427.00**
			Total	**£102,247.00**
	Contingency @ 5%			£5,112.35
Shipping and Clearance Charges - estimated				**£5,000.00**
			Final Total	**£112,359.35**

References

Thompson, G., 2000a. Review of MVO seismic monitoring, August 2000. MVO Open File Report 00/02, Montserrat Volcano Observatory.

Thompson, G., 2000b. Upgrading the MVO seismic data acquisition and analysis systems and collaborating with SRU. MVO Open File Report 00/03, Montserrat Volcano Observatory.