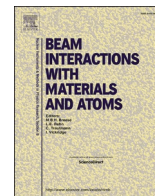




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Introduction of interactive remote monitoring at SUERC

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ABSTRACT

SUERC has implemented remote control of routine and experimental NEC spectrometer operations.

Through secure tunnelling, a dedicated laptop for each spectrometer can execute parts of the AccelNET (Accelerator NETWORK control system) suite and communicate remotely with the underlying database: instrument control pages are accessible and changes to the run list can be effected in the dosimetry manager (DMAN). X-forwarding facilitates the use of the *abc* data reduction software upon the large remote dataset, allowing the operator to evaluate data quality mid-run, while screen-sharing is employed to provide flexible access options. AccelNET's read-only html output (formerly the predominate form of remote monitoring) remains accessible for 'casual' progress checking by non-operators.

While there are limitations to each technology used, these changes to our setup and operating procedures have had positive effects both for operators, and upon the smooth delivery of sample data.

1. Background

The SUERC AMS Laboratory operates two NEC AMS instruments for routine sample measurement, measuring approximately 8000 cathodes across ^{14}C , ^{10}Be , ^{26}Al , ^{36}Cl , and ^{129}I in an average year [1–3].

With batch measurement taking several days, there is a need for frequent monitoring of the machine parameters and the incoming data to ensure the run proceeds smoothly and does not wastefully consume sample material should run conditions change over time.

The requirement for this monitoring continues offsite outside of normal laboratory working hours. Formerly, remote monitoring was undertaken using the read-only web interface, with any necessary adjustments or intervention, however minor, requiring attendance at the laboratory. This effectively placed an operator on standby to make this journey for the duration of the run.

Since 2018, each instrument has a dedicated laptop providing secure remote access to the accelerator control system. This allows for more interactive methods of data monitoring and provides means of making minor adjustments to machine parameters without need to travel to the laboratory. Where more intensive intervention is required, a run may be paused or stopped remotely to preserve sample material until lab attendance is possible. However, in many cases, a small adjustment will allow a run to continue uninterrupted.

It should be noted that AccelNET [4] operates as a networked suite of control programs. These may run across a number of connected client

computers with reference back to an underlying database on the main control computer. The text below details the laboratory's experience of extending that network to incorporate remote access.

2. Methods

There are four main methods of remote monitoring and access employed by the laboratory: Remote AccelNET, X-forwarding, screen sharing and the web interface. Each permits usage of components of the AccelNET control system as described below. A summary of the methods and their usage is given in Table 1.

2.1. Remote AccelNET

The primary method of remote access used is AccelNET on a laptop. Most system functions are available to the operator with the usual AccelNET interfaces appearing on the laptop screen as they would on a lab computer. The client programs are run on the laptop and connect back to the control system server. Operators use this for remote monitoring of incoming data (using the dosimetry manager client *DMANmng_r_v2*) and may choose to run a strip chart (*pen_recorder*) to track instrument conditions. Adjustment of the machine parameters is possible through the AccelNET control pages.

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Table 1
Summary of remote access methods and usage.

Access Method	Operation	Usage
Remote AccelNET	Client programs run on laptop and communicate with server	Access to control pages, dosimetry manager, strip chart, etc.
X-forwarding	Client program runs on lab computer but displayed on laptop	Data reduction using <i>abc</i> software – avoids moving large dataset over network
Screen Sharing	Lab computer controlled remotely over the network	Additional method for occasional use in absence of laptop
Web Interface	Read-only web pages output by AccelNET	Run monitoring by non-operators

2.2. X-forwarding

A complimentary method of accessing some system functions, X-forwarding allows a program to run on a remote computer (i.e. in the laboratory) with the user interface shown on the laptop. This is used where it is not possible, or not desirable, to run the program on the laptop. For example, performing a mid-run data reduction using NEC's *abc* data reduction software to evaluate the quality of data being produced. As remote users are dependent on the speed and reliability of their home broadband connection, running programs which remotely access large datasets could result in a poor experience or even data corruption. By using X-forwarding, the *abc* application is executed on a lab computer. All access to the run data remains within the lab, with only the display transmitted remotely back to the laptop.

2.3. Screen sharing

As an alternative access method, a computer in the laboratory can be remotely controlled. This screen sharing offers the remote user any function normally available while physically seated at the keyboard but can be slow to respond and ties up that computer for staff in the lab. While mainly used 'on-campus', e.g. from an office elsewhere in the building while warming up the ion source, this can be also be employed should the operator with the laptop be temporarily unavailable.

2.4. Web interface

The AccelNET web interface was formerly the main method of monitoring runs remotely. It remains in continued use, but this is now much reduced. The remote user simply requires a web browser to access basic system status and dosimetry information. The read-only nature of the web pages means there is no possibility of accidentally making changes, making it appropriate for use by non-operators who wish to monitor run progress.

3. Setup

There are three main steps in setting up remote access: installation of software on the laptop, setup of networking, and configuration of security settings. Except for the new laptops, no additional hardware was required to complete the setup.

3.1. Laptop setup

There are no particular hardware requirements for the remote laptop provided the screen size is large enough to comfortably view the control system elements and a mouse is attached to enable middle-click. As the different generations of instruments in the laboratory use different versions of AccelNET, the setup of each laptop is tailored to the system it is intended to interface with. An operating system (a version of Scientific Linux) is installed to match the control system computer. This is partly to ensure compatibility, but also provides continuity in user experience

between the local and remote systems. Users and groups are set up to mirror the main control system (i.e. user *csadmin* with UID 500 and group *cs_admin* with GUID 1010). To support the control system menus, the Tcl/Tk language and toolkit are installed. Finally, a local copy of the AccelNET software is made on the laptop ensuring appropriate file permissions are granted to user *csadmin*. This permits the individual programs to run on the laptop and connect back to the server.

3.2. Networking

Remote connection to the control system is made possible using secure SSH (secure shell) tunnelling. Links are set up through a local client computer in the lab, such that the remote laptop and the AccelNET server appear to be on the same network, avoiding direct connection to the main control system. One of these tunnels is required for each service that must be accessed on the server, e.g. the control system database or dosimetry management server. Two small scripts manage this on each laptop: one to start the tunnels (Fig. 1) and one to stop tunnelling (Fig. 2). The *start-tunnels* script opens the connection to the control system and records the associated process identifier in a file. This is later used by the *stop-tunnels* script to end that process and close the connection.

Three tunnels are required to allow basic remote AccelNET access. Two permit communication with the underlying database (*dbman* on port 6100, *pgman* on port 6120) and, without these, no control pages can be displayed. The third allows access to dosimetry management (*DMANserv_v2* on port 6150) such that measurement results can be seen and changes to the run list made. For each of these services, an amendment is made to the *environs* file in the laptop's main AccelNET directory: the values for *DBMAN_HOST*, *PGMAN_HOST* and *DMAN_HOST* are all set to 'localhost' (i.e. the laptop itself). Any attempt to connect to those services will be captured and redirected through the tunnels to the control system.

While these three tunnels provide the majority of features for which remote access is desired, the setup needed to allow amendment of the dosimetry gates is slightly different. The dosimetry histogram display client program (*HISTmngr_v2*) cannot be executed remotely as it shares memory with the list processor (*listp_v2*) so must necessarily run on the same computer. In this case a tunnel is set up to the control system (port 6621 on the laptop, port 22 on the control system) to permit *HISTmngr_v2* to run on the control system but appear on the laptop screen via X-forwarding. The window is displayed using the command in Fig. 3.

One final tunnel is established to support the alternative screen sharing access method. In this case the target is the shared computer in the laboratory, rather than the control system, and is connected using the VNC port 5900.

3.3. Security

Security is naturally a concern for any network-based system. For the laptop to work remotely, it is necessary for the lab computer hosting the tunnels to accept connections over SSH, therefore appropriate modifications must be made to firewall and access control rules to permit this.

Access is limited using SSH keys as credentials between the laptop and laboratory computers. These keys must be pre-shared in order for a connection to be made. If the laptop cannot prove its identity to the lab computer through possession of a known authorised key, access will be refused.

In its intended function, the laptop will be off-campus when in use. For the laboratory computers to be visible to the laptop, a connection must first be made to the University network over VPN. The script to start the secure tunnels may then be executed, and control of the accelerator assumed.

```

start-tunnels
#!/bin/bash
# stop existing tunnels first
./stop-tunnels
echo Running tunnels to AMS
echo Do NOT close this window
echo Use stop-tunnels when you are finished
# create ssh tunnels
# format is localport:remotemachine:remoteport
# ssh command is backgrounded to obtain its PID
ssh -N \
-L 6100:<control_system_address>:6100 \
-L 6120:<control_system_address>:6120 \
-L 6150:<control_system_address>:6150 \
-L 6621:<control_system_address>:22 \
-L 5900:<lab_screenshare_address>:5900 \
<lab_tunnel_host_address> &
# store pid for stop-tunnels script
echo $! > ~/.ssh.pid
# wait for ssh tunnels to close
wait
# closedown message
clear
echo Closing tunnels
echo PLEASE WAIT
sleep 5

```

Fig. 1. Script to setup the connection to the control system.

```

stop-tunnels
#!/bin/bash
# check to see if a .ssh.pid file exists
# if so, checks to see if associated task is in /proc,
# and attempts to kill it
if [ -e ~/.ssh.pid ]; then
echo "Stopping tunnels"
pid=`cat ~/.ssh.pid`
if [ -e /proc/$pid ]; then
kill $pid
fi
rm ~/.ssh.pid
sleep 1
fi

```

Fig. 2. Script to disconnect from the control system.

```
ssh -C -X -p 6621 localhost "HISTmngr_v2 <options> " 2>/dev/null &
```

Fig. 3. Command to run the dosimetry histogram display client over X-forwarding.

4. Practical considerations

4.1. Multi-user concern

With the introduction of multiple methods of access to the control system, concerns were raised about the possibility of many users trying to operate the instruments simultaneously. In theory this could lead to multiple small adjustments having a larger additive effect than was intended by either party. An example might be raising the caesium oven temperature to address a falling beam current. If the second person to spot the low current is unaware the oven voltage has just been raised, they may raise it for a second time. This overcorrection could potentially result in too high a beam current.

This concern is mitigated through staff working practices. The laboratory works on the principle that an operator takes charge of a batch of samples from receipt, through measurement, to reporting results to submitter labs. This remains the case with remote access, with possession of the dedicated laptop acting as a physical token signifying the controlling operator for that batch. Should another member of staff

notice an adjustment is required, they will contact the controlling operator. Team communication is key to managing these concerns. While a shared notebook has been considered, for any significant events or changes, a group message often remains most effective.

4.2. Limitations on usage

While it is possible to control many of the instrument functions remotely, it is not always sensible or practical to do so. Any operation that is liable to cause an unsafe situation in the machine hall must not be undertaken remotely.

The most obvious example is tuning of the instruments, particularly the tandem accelerator, as this process may produce excess radiation. It is not possible for a remote operator to properly follow the laboratory safety protocols (i.e. ensure the hall is evacuated prior to disabling radiation interlocks) and therefore tuning must not be performed remotely. In practice this would not arise as, aside from the safety aspects, it would be impractical to tune without physical access to the control dials normally used to adjust parameters.

A further example is switching on power supplies following maintenance. While this is obvious in most cases, as the power will be restored to test the component when work concludes, there is a potential this may be overlooked following routine work such as an ion source clean and rebuild. It is recommended that the initial power up of the source be performed in person, should any ‘sparking’ occur this will be immediately obvious to the operator and the source can be switched off to avoid damage.

The remote system is intended for minor adjustments only, or to pause or stop a run until attendance at the laboratory is possible.

5. Summary

Using networking methods and a few small modifications to command execution, the control system network for each instrument in the laboratory has been extended to incorporate a laptop providing remote ‘off-campus’ access to the system.

Production of data has been improved, with timely remote adjustments reducing the time lost to measuring cathodes under sub-optimal conditions. The ability to perform remote data reduction using *abc* has been particularly well received by users as this allows more detailed and effective interrogation of the data mid-run.

These changes to the laboratory operating methods have brought about a positive effect on both operators’ work/life balance and the smooth delivery of sample data.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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