Some thoughts about Data Acquisition, Storage and Transmission for the AASTO

The fields of data acquisition, data storage and data transmission are all fast moving.

For instance, recently: global communication satellites have become available, very robust silicon based ‘flash’ storage has reached reasonable densities at reasonable cost (eg US$500 for 128MB) rotating magnetic disk technology has surpassed optical disks for storage density and is extremely cheap (eg 13GB US$200).

The challenge is not to build a working system but to build one that:-

1. Is able to grow with the available technology without continual re-engineering.
2. Allows maximum exploitation of the scientific data.
3. Allows easy additions or changes to the experimentation.
4. Is robust and reliable.
5. Remains cost effective despite changes in technology and scientific goals.

I will argue that the centralised DAU approach taken by both the US and UK AGOs does not meet the above general requirements, and that a distributed data system is more flexible and more robust.

A centralised approach is inevitably complex as it has to cope with a wide variety of data formats from a wide variety of experiments – tending to result in highly engineered specialised systems which have limited flexibility and limited life.

A distributed system on the other hand maximises the use of commercial component technologies and is highly flexible.

To some extent both the US and the UK AGO platform have outgrown their own centralised approach. The first experiments to be deployed were relatively simple and all of the computing functions and data storage could be handled by one computer. With the addition of more complex experiments this approach becomes impractical and now many experiments are responsible for their own control and computing functions, and yet data storage has continued to be handled centrally – typically by a bank of optical disks.

Are there any benefits in centralised storage:

1. Its easy to arrange for the data all to be time stamped with the same time standard.
2. All the data ends up in one place and hence is easy to manually pick up.
3. All the data ends up in one place and hence it is relatively easy to arrange onward transmission by satellite or some other communication system.

I will cover how point 1 and 3 can be addressed in a distributed system during the example description that follows. Point 2 is a fairly trivial benefit.
In a distributed system each experiment is responsible for its own data storage. In the most simple system each experiment would be totally autonomous with no connection to each other – for instance you might have the MISM and NISM storing their own data to their own PCMCIA flash disks. However, some services such as satellite communications and GPS time stamping are best provided centrally.

Why are these services best provided centrally whilst data storage is best provided locally – because data storage is essential, some experiments may choose not to use the central services but all experiments will require data storage, and the requirements of data storage vary hugely from one experiment to the next whilst the requirements of GPS time stamping and of satellite communications are more or less fixed (in one case by definition and in one case by the available technology). Furthermore, a failure in centralised data storage can mean many months of missing data whilst failure in communications or GPS timing are less drastic.

Some experiments, especially those based on imaging technology such as the AFOS, are capable of generating very large amounts of data. Transmitting large amounts of data onwards, or storing large amounts of data on robust media such as silicon flash disks or optical disks, is very expensive. However, limiting the amount of data acquired can be scientifically expensive as it limits both the usefulness of the experiment and the chance of catching rare events. A distributed data storage approach lends itself to a solution to this dilemma in that it more easily allows experiments to record their data to a variety of media allowing a hierarchical approach, for instance summary data could be stored to a robust but expensive medium whilst all the raw data is stored to far cheaper medium but with greater risk than it will be lost.

Flash memory – very robust and reliable, very low power, densities currently to 320MB on a PCMCIA card. Most expensive per MB

Optical Disk – reasonably robust, high power, densities around 2GB per disk.

Magnetic storage – least robust, medium power, very cheap, most aggressive development path.

So for instance you could have the AFOS store summary data to PCMCIA Flash card whilst the raw data rather than being discarded is stored on normal magnetic disks.

Could all the data be transmitted from the AFOS?

Global satellite communication technologies are a massively expanding field, low bandwidth systems exist already and many higher bandwidth systems are in development. A very rough and ready summary is:

ARGOS – already working, one way message passing, very low data rate (24 bytes a day!), use limited to system health, low power.
ORBCOM – already working, two way message passing, data rate 2400baud but each message size limited to about 200 characters - use probably limited to system control and extraction of sample data. Low power, commercially available, cheap at about US 0.01 per character.

IRIDIUM – more or less working now, real time phone line connection, data rate currently 2400 baud, Real time control of experiments, extraction of sample or selected data. Low power, commercially available, approx. US10 dollars per minute.

IMARSAT ICO – expected 2000-2001, real time phone connection, data rate expected to be 4800baud. Real time control of experiments, extraction of sample or selected data, Low power, commercially available, call costs expected to be lower than Iridium at about US4 per minute.

TELEDESIC – expected 2004, world wide LAN type connection with 2Mbaud uplink speed, would allow most data to be retrieved in real time. Costs unknown at this time.

There are several non commercial satellite systems such as AMSAT and VITA which typically offer a message passing service capable of several 100Kbytes per day. Although these are operated non-commercially and would require more engineering input, the extra risks may be acceptable for the low cost of data transmission.

Non-satellite systems such as HF radio or meteor scatter radio potentially offer cheap transmission costs within Antarctica, although the engineering effort and the power levels are both high and not helped by the polar ionosphere.

In the short term it is unlikely that it will be financially viable to extract all of the data from a system such as the AASTO, hence local storage for all the vast bulk of the data will be required. Even with a data transmission system in place, it is likely that one would continue to store essential and summary data to a robust medium within the AASTO to insure against failure of the transmission system. Local storage of the ‘raw’ data to magnetic disk is so cheap compared to its transmission, that again it makes sense to retain the storage to guard against failure of the transmission system and to provide a backup until it can be verified that the data is safely duplicated elsewhere.

In a distributed data system, the engineering consists of defining a series of interfaces that the individual experiments can opt into if desired. For instance:

GPS time. NMEA serial (listen only) and 1 PPS output. Perhaps time packets on LAN as well.

Satellite communications. Likely that calls instigated from outside region, this can then wake a controlling computer can then respond by either direct access of experiments disks if a LAN exists, by issuing control bytes over serial lines, or by direct control of
power lines, resets etc. It is likely that relatively few long calls are going to be most efficient.

Experiment control. This would generally be autonomous but if control or modification of operating parameters by satellite is required then general mechanisms useful. One such mechanism is where an experiment takes its operating values from a table, but can choose to update the table on instructions received over a serial or LAN line – always a good idea to include a default table and a way of forcing operation from it.

Under such a regime if an extra experiment is needed then it can be totally stand alone, or could accept limited services such as getting time from the NMEA serial stream, or can be totally integrated with LAN connections etc.

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