CORS Network Case Study

General description
The network core of original pilot 6 stations was established in 2002 as a cooperative between 3 public sector entities (one city, one utility, and one city-owned utility). The central processing centre (CPC) was established by Seattle Public Utilities (SPU, a department of the City of Seattle) to improve the capabilities of its own surveying interests. Other public and private sector entities soon contacted SPU to see if more stations could be added. A cooperative was formed; the Washington State Reference Network in 2003.

SPU has purchased and established the CPC with RTN software and multiple servers. SPU continues to operate the CPC and administer the network. 50+ public and private partners have contributed CORS or other infrastructure/funding. Liaison and data sharing with adjacent and inclusive other RTN has been established. Non-partners may use the network via nominal yearly contributions to offset operations costs (subscriptions). The WSRN is prohibited from seeking profit and must invest all subscription fees into the network.

The driver was rising soft costs for capital improvement projects and public works; specifically surveying, mapping, and construction.

Manager(s)/Organisation(s)
Individual partners own, operate, and maintain individual CORS, or groups of CORS. The CPC is owned and operated by SPU. Partners attain membership in the WSRN by signing simple data sharing agreements with SPU. The fundamental of these agreements is that:

Raw data streams from viable CORS = full data access accounts

Therefore no single entity “owns” the network. The administration of the network is by SPU under the same agreements. The partners and users have the option of meeting as technical advisory groups. SPU abides by the recommendations of these groups unless there are specific technical or financial impracticalities.

Any subscription income from non-partners goes directly to operation of the CPC. Any excess is invested into network infrastructure on as equitable a basis is possible; critical needs are addressed first.
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Type of equipment, description of a “typical” station

Mounts vary from the drill-brace (UNAVCO/PBO style) to concrete stepped-pad and pillar, to building mount. Where possible, the drill brace and concrete mounts are employed. If a building mount is used, it is rigorously tested over weeks to determine if it produces the same (or sometimes better) results than the other two types.

Our cooperative does not limit brands of receiver or antenna for inclusion in the network; only that they are dual-frequency with a geodetic-grade antenna, and that they do not have substantial internal latencies. We have 64 Trimble, 14 Leica, 14 Topcon, 1 Sokkia, and until recently had a Geotracer. All new and replacement receivers are multi-constellation. While most receivers are specifically of the ‘reference station’ models from the respective manufacturers, some are not and also require a serial-to-IP device. Standard surge protection is required, lightning protection, and where the stations are connected by a modem, we usually install some kind of remote (dialup) power management devices.

Description of Control Centre

The control centre (CPC) is a cluster of server (Win Server 2003) installed in the DMZ of the SPU secure server facility. The cluster consists of pairs for redundancy of function; 2 for connectivity, web, NTRIP caster, data file writing, 2 for RTK processing, 1 for positional quality & integrity management. A redundant CPC is being established at a university with 3 servers (1 for comms/NTRIP caster, 1 for RTK processing, and 1 specifically to monitor the effects of plate tectonics).

The RTN software used by the WSRN is the Trimble GPSNet suite, and the integrity-monitoring package is Trimble Integrity Manager. We also employ the Rover Integrity Manager.

Communication between station and control centre include: Cable, LAN, WLAN, WAN, DSL/ADSL, Satellite (VSAT), but have used dial-up (RAS Server) in the past. Most connections have direct access to the sites via static IP, but some DSL (DHCP) and closed networks (like city governments) only allow a one-direction flow (i.e. setting up the receiver, or a serial-to-IP device at the remote site as a “device-client” to a dedicated port on one of the data centre servers). In the case of adjacent networks sharing data, we use NTRIP server-caster-client.
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Stations
Number: 79 currently connected, final build will be 93 plus 6 rover integrity monitor stations.

Different classes: 70 will be classed as geodetic primary (digital level runs will be completed between these). Of these 70, it is hoped that eventually 40 will be included in the National Geodetic Survey array of “Collaborative CORS”, and the data from those will be included in the online positioning service “OPUS”. 23 others will serve real-time purposes only, and an additional 6 will serve as “rover integrity stations”.

Average distance between stations: 30-50km in the western party of the state, 30-70km in the More rural (and more open sky) eastern part of the state.

Map of distribution of stations:

Services
- Network: VRS CMR+, VRS RTCM2.3, VRS RTCM3.1, DGPS, FKP, MAC (aka 3Net). All via IP and NTRIP.
- Single-Base: CMR+, RTCM2.3, RTCM3.1. All via IP and NTRIP.
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- DGPS: VRS RTCM2.3 and Single base RTCM2.3. All via IP and NTRIP.

- Post-processing: Logging 1Hz Rinex in hourly files for direct download or automated requests (i.e. decimation, multi-station, and file joining) via web application. Also Virtual Rinex.

**Accuracy Levels:** all stations must meet 10mm network accuracy (automated integrity monitoring with periodical full network adjustments). Typical Network RTK results at: 1cm horizontal, 2-3cm vertical.

**Correction data acquisition by:** NTRIP and any IP connectivity; GSM, GPRS, CDMA, Wi-fi, Broadband wireless. Some users access corrections via hardwire Internet at job sites and relay via base radios

**Constellations:** mostly GPS at this time.. GLN available from any GLN capable station via single-base, and GLN via VRS where 3 or more GLN capable stations are adjacent. More as time goes on. Sparse-GLN algorithm to be implemented in remote areas. All new or replaced stations will be multi-constellation.

**Users**

The network was developed mainly to serve partners (contributors and operators of the CORS infrastructure); partners are entitled to up to 6 accounts per active CORS (or if there are multiple partners for one CORS they share the accounts). 550+ partner accounts

**Non-partners** pay a yearly fee to offset operations costs. Profits are prohibited; all subscription Income must be invested in the network. Non-partner accounts are $1900USD, 3 for $5700USD, or 10 for $10000USD. 50+ subscriber accounts. 90 free day test accounts.

**Academic Institutions** are typically contributing partners in some fashion. But for pure research one free account is available for each institution or project. 5 academic and scientific institutions have accounts.

**Equipment vendors** and resellers are granted free test accounts to develop training materials, demonstrate equipment, train customers, and test new models.

**Key Problems**

**Physical** problems mainly are with respects to communications. While latency is no longer an issue with all but one station (an older receiver with high internal latency), there are 5 with comms that can drop off with no notice. We employ several types of remote restart devices for those (phone, IP, timers, or manual) to mitigate. With many
stations being in austere locations, we have few options for redundant communications; nearly all of our stations have no redundant comms.

**Network servers and software** are the least of our problems. With redundant servers, and procedures in place to keep the system monitored we have an up time average of 98% for real-time processors. This 2% includes scheduled maintenance, and this typically happens in off-peak hours. Down time during peak hours has usually been due to network operator error.

**Support calls** are typically to report that the user is unable to connect/initialize. These are most often rover communications (cellular connection/configuration), password try count is exceeded, or local conditions (sky, multipath) make initialization difficult.

**Our biggest challenge with respects to users** is that most have not worked with earth-centred datum’s, and are unable to reconcile the inconsistencies between our network datum (we constrain to the national adjustment of the NGS CORS) and the legacy control systems. The concepts of calibration (localization and adjustment) to local control systems. The concepts of calibration (localization and adjustment) to local control) has been difficult to teach as there are few regional or federal experts with time/funding to teach.

**Business** problems were mostly encountered in initial funding of the data centre. SPU required an Asset Management Review to present the findings of the pilot, and a cost benefit projection over 12 years. Recovery of initial investment for the data centre was projected to 2-3 years, but this took only 1.5 years.

The **model for the cooperative** was another challenge. For the public sector entities (cities, counties, state agencies, federal agencies) the spectre of a formal stand-alone organization would have taken perhaps a decade to develop. But, by state law an “inter-local agreement” may be formed when more than two entities share agreements with a common party. In this case, SPU could be the common party. Mutual management, cost, and revenue sharing would have required a much more formal organization. It was decided that a simple data sharing agreement (separate agreement between each individual CORS owner/operator and SPU (i.e. raw data in exchange for accounts) was the best solution. The agreement took 18 months of legal review. It contains sufficient “hold harmless” clauses to protect each individual partner from direct liability. Likewise, each non-partner agrees to use the network on an “as-is” basis. No services are guaranteed in any way. The cooperative may only be liable for the balance of a yearly subscription if service were to be interrupted. We modelled such agreements after typical cellular service agreements.

**Ongoing operations** funding was a challenge until the subscription levels reached enough to offset such costs. SPU still contributes the majority of operations funding, but internal savings certainly offset this.
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Individual partner business cases. During the development of the network, each partner had to make a business case to their own organization to justify investment in the CORS and their own respective rovers. This varied from a simple business case (based on numbers from other partners) to sometimes years of negotiations. Each case ultimately proved to be less unique than originally thought, but in the course of discovering how simple the business case could be, the cooperative had to make over 120 presentations to partners and their management (that is a lot of exhausting PowerPoint presentations).

Future plans
Completing the build-out of 93 stations will happen in 2008 (with nearly all equipment purchased only agreements and communications issues need to be resolved).

Upgrade to multi-constellation; at least with sparse spacing, then all stations; by attrition, likely a four year process.

Academic use of the network for real-time plate tectonics studies. This movement data will help us develop the transformation databases needed to implement that feature via RTCM3.1.

Statewide communications options. Partnerships with entities that operate wide-area IP capable 700-800MHz radio networks to develop correction relay options for users in poor-cellular areas of the state.

Submit 40+ of our CORS to the National Geodetic Survey (NGS) cooperative CORS program. Submit several more stations as IGS stations. Stations are already available for the NGS Height Modernization program (i.e. establish updated values for our vertical reference monuments, tide stations, gravity stations, etc).

Become self-sufficient with respects to operating costs, and partially funding a replacement cycle for the CORS.

Contact information

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