SOAR Remote Observing: Tactics and Early Results

Gerald Cecil[1a], J. Adam Crain[a]

[a] Dept. Physics & Astronomy, Univ. North Carolina, Chapel Hill, NC 27599-3255

ABSTRACT

Travel from North America to the 4.1m SOAR telescope atop Cerro Pachon exceeds $1000, and takes >16 hours door to door (20+ hours typically). SOAR aims to exploit best seeing, requiring dynamic scheduling that is impossible to accomplish when catering to peripatetic astronomers. According to technical arguments at www.peakoil.org, we are near the peak rate of depleting world petroleum, so can expect travel costs to climb sharply. With the telecom bubble's glut of optical fiber, we can transmit data more efficiently than astronomers and "observe remotely". With data compression, less than half of the 6 Mbps bandwidth shared currently by SOAR and CTIO is enough to enable a high-fidelity observing presence for SOAR partners in North America, Brazil, and Chile. We discuss access from home by cable modem/DSL link.

Keywords: Video conferencing, Internet2, data compression, remote observing, LabVIEW, SOAR

1. INTRODUCTION

As described previously[1], SOAR is deploying multiple "hot" instruments, and data acquisition by a SOAR partner will be scheduled initially in half-night blocks. By reducing cost and time overheads, student participation can be maximized, programs can be adjusted dynamically to anticipated weather and seeing, and problems can be diagnosed by instrument PI's at partner institutions. This paper updates our previous report[2] on plans for remote use of the telescope and instruments to include tests between UNC and SOAR during commissioning.

2. COMPRESSED VIDEO

Key to remote use of observatories is the Internet2 (I2, www.internet2.edu), a not-for-profit consortium led by >200 US universities that is developing and deploying advanced network applications and technology. I2 has both the quantity and quality of IP connectivity required to support reliably projects that incorporate intensive video conferencing (VC, e.g. telemedicine, multi-institutional collaborations). In the US, I2 runs on the Abilene network (http://abilene.internet2.edu) that connects regional network aggregation points called gigaPoPs. To establish how any US institution can connect to a nearby gigaPoP and the I2, use the network map www.abilene.iu.edu/images/logical.pdf and free Windows/Mac software at http://detective.internet2.edu. At a typical I2 connected institution, IP traffic will route automatically between your computer and those at other I2 sites without special activation. It is a goal of Abilene to provide 100 Mbps connectivity to every member computer. Essentially all US NOAO users are already, or can be, connected via I2 to SOAR thanks to a contract between Global Crossings Inc and the US NSF that stretches I2 from a gigaPoP in Florida to Chile. (The contract expires in 2004, but is being renegotiated). Abilene is peered with 40+ similar efforts in other countries (e.g. CANARIE in Canada, SURFnet in the Netherlands, see http://international.internet2.edu/partners.) Institutions other than universities are granted access to an I2 network via the "Sponsored Education Group Participant" process (SEGP, http://k20.internet2.edu/segp/background.html). UNC plans to sponsor the Chapel Hill/Carrboro City Schools within two years. Once this is accomplished, school groups will be able to join SOAR observing sessions.

Currently, high-end VC hardware tops out at ~3.5 Mbps. The standard H.263 video compressor/decompressor (codec) is supported in hardware sold by Polycom, Tandberg, and Vcon among others for upward of $1000. We have also obtained excellent results from *software* codecs: a PC with at least a 1 GHz Pentium III CPU can run Vcon's vPoint (www.vcon.com, $245 with camera and headset, Fig. 1) Windows software to connect to another H.263-equiped system at whatever speed is required. This software controls remote camera pan and zoom if available, gives excellent monaural sound, and allows multiple parties to connect to your PC (which acts as a Multi-Conference Unit, MCU). It works with any USB-connected camera. We like the Logitech Laptop Pro camera ($75 in 6/04); it has good resolution and color fidelity. It cannot zoom or auto focus, but can be panned over a 30° arc by the remote site or locally by its excellent and accurate face-tracking software. We have maintained a 768 kbps wireless VC to SOAR on a notebook computer carried around the UNC Physics & Astronomy Dept.

[1] Gerald@thececils.org; phone 919-962-7209; fax 919-962-0480

Very acceptable VC can be done at 384 Kbps on I2. In contrast, the "Commodity Internet" needs at least this bandwidth for noticeably poorer images and sound, yet does not get it reliably because of router latency issues; it was simply not designed for the demands of VC. While the vPoint software supports a less demanding Viewer+ mode, whereby you receive remote video but do not broadcast it, a newer video codec • H.264 (MPEG-4 Part 10) • now enables high-quality, bidirectional VC on congested and lower bandwidth consumer cable modem (CM) and DSL. We have used DSL to VC to SOAR from a country home 6 miles from Chapel Hill. A CM in town provides even better performance (Fig. 1). Both of these "consumer broadband" options are asynchronous: downloads to you are >768 kbps (often >3 Mbps after midnight on a CM, whereas evenings are most congested). But, your outbound signal must reach 64 kbps audio + 384 kbps (H.263) or 192 kbps (H.264) video for reasonably fluid VC, service that in Chapel Hill is currently $54 monthly for dedicated DSL or $42 for shared CM. With rapid market penetration of consumer broadband and H.264, we expect that by 4Q 2004, most UNC users will be able to VC from home to SOAR. One important consideration of such use is security. The data streams can be encrypted, but the vPoint software uses dynamic UDP connections that open well-known pinholes in your firewall. Although SOAR will link to the remote user via an ad hoc Virtual Private Network (VPN), a hardware firewall is still essential.

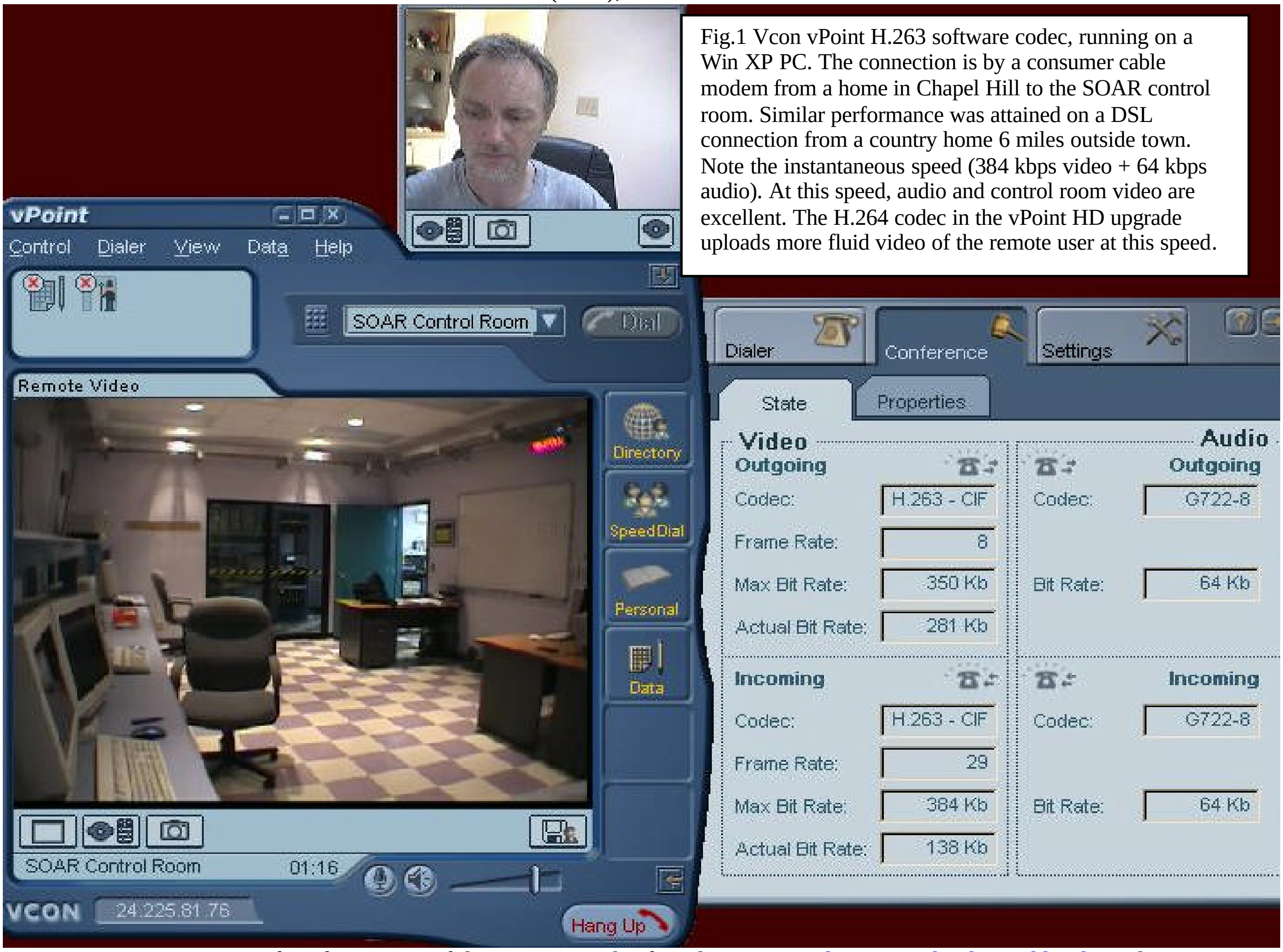


Fig.1 Vcon vPoint H.263 software codec, running on a Win XP PC. The connection is by a consumer cable modem from a home in Chapel Hill to the SOAR control room. Similar performance was attained on a DSL connection from a country home 6 miles outside town. Note the instantaneous speed (384 kbps video + 64 kbps audio). At this speed, audio and control room video are excellent. The H.264 codec in the vPoint HD upgrade uploads more fluid video of the remote user at this speed.

First attempts at VC are often fiascos. Useful pointers can be found at www.videnet.gatech.edu/cookbook, and an amusing cautionary video can be viewed at http://uwtvproduction.org/convergence.html (select The Videoconference Zone). An often neglected aspect (e.g. Fig. 1) is to approximate "eye contact" whenever appropriate. A few suggestions:

- Position camera and monitor/video window as close together as possible.
- The farther you are from the camera/monitor combination, the more it appears to the remote participant(s) that you are looking at her/him/them when you look at the monitor. To really approximate eye contact, look at the camera not the monitor.
- You must be well lit for the remote site to see you clearly. Spotlights, mid-brightness clothing, and dark walls do not wash you out. We experimented with IR LED security lights that are bright to TV without dazzling the eye. However, at present a prohibitively large number are required for effective diffused VC illumination.

We expect UNC faculty and post-docs to use SOAR remotely from an office or at home. Many notebook computers can drive an independent 2nd external LCD, providing enough combined screen area for VC and instrument control. However, it is impossible for others to participate in the observing session. To train students and to highlight our efforts, we therefore built the Henry Cox Remote Observing Center (Fig. 2). Here, two projectors ($4200 each) and a Matrox Parhelia graphics board project an 11-foot diagonal, 2730x1024 pixel digital display. A wall mounted, 32-inch LCD widescreen HDTV and VC unit connect to the SOAR control room at up to 1.3 Mbps. This facility is temporary until a UNC science building is finished in 2006 that will house near its entrance a compelling, 13-foot wide, 3840x1024 pixel display.

MPEG-4 de/compression is computationally relatively expensive, so H.264 has emphasized attaining the same video quality as H.263 at half the bandwidth (e.g. Polycom's $2000 V500 unit tops out at 512 kbps). The new vPoint HD software codec requires a Pentium 4 HT (hyper threaded) or Pentium M CPU. The result is worth the expense of a hardware upgrade, see the video clips at www.pixeltools.com/h264_paper.html. As suitable DSP chips cheapen, H.264 will be applied to much higher bandwidth connections. DVD-quality broadcasts at ~1 Mbps will be available by 3Q 2004, entirely feasible bandwidth to SOAR now. In April 2004, Apple Computer Corp. demonstrated software decompression of MPEG-4 HDTV at several Mbps. Clearly, the possibility of a high fidelity, virtual extension into the SOAR control room is near.

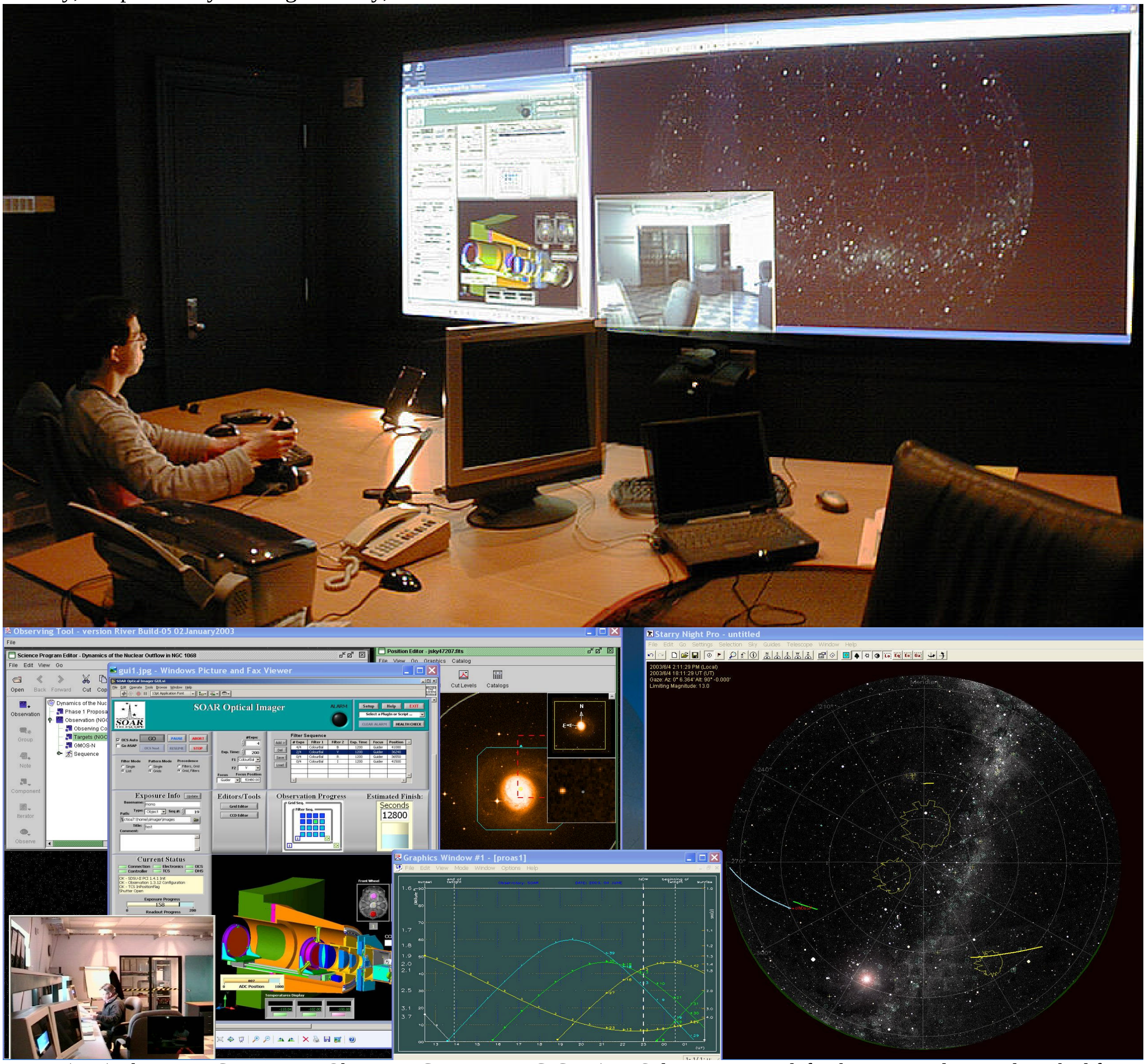


Fig. 2. (Top) The Henry Cox Remote Observing Center at UNC-CH. (Mr. Sulu navigates at left, photon torpedoes are launched from the right-hand station.) Optimizing screen use is an ongoing challenge; the layout projected here is a feeble early prototype. We have since moved VC off-screen onto an LCD HDTV mounted on the right-hand wall. The table shown now "joins" one in the SOAR control room. We select among four different virtual desktops using the freeware at http://find.pcworld.com/42722; one handles a concurrent IRAF analysis session running on Linux/X. (Bottom) Example screen display, incorporating many of the elements described in this paper.

3. MINIMIZING BANDWIDTH FOR INSTRUMENT CONTROL

The quickest way for a distant user to control an instrument or telescope system has been to export the entire instrument console to their desktop. This has been done for 15+ years with the X11-window system, and now even Windows XP Pro supports remote logins. However, these connections require >5 Mbps burst bandwidth; otherwise mouse cursor and window redraw latencies become too irritating or unreliable. Latencies are shorter at similar bandwidth in newer packages such as VNC (according to www.vnc.org 20 million copies of this client/server freeware have been downloaded since 1998). As a quick and dirty connection to a new application, we at UNC use VNC to access a single screen on Linux PCs atop Cerro Pachon. However, VNC to more than a single screen takes too much bandwidth for routine remote observing.

Bandwidth is reduced dramatically if only simple elements are drawn within a "terminal" window using "curses"-based (after the Unix library of that name) bit-mapped graphics. Arrow and Tab/backspace keys move between "form fields", and select from drop-down lists and other very simple GUI elements. Very short strings are passed between the remote server and local client. However, users today are accustomed to more informative graphics. Dials, meters, and strip charts better illustrate trends, control ranges, and settings of "virtual instruments" (VI's) to sleep deprived users, graphical elements that are displayed poorly by "curses". We have therefore sought to enrich the user's interface while minimizing control bandwidth. Because SOAR instruments and most of the telescope systems are coded graphically in LabVIEW, we have developed our solution in that environment. It is helpful that LabVIEW user groups are active, and develop and share clever VI's. There may soon be a "LabVIEW for Astronomy" news group to discuss useful tools.

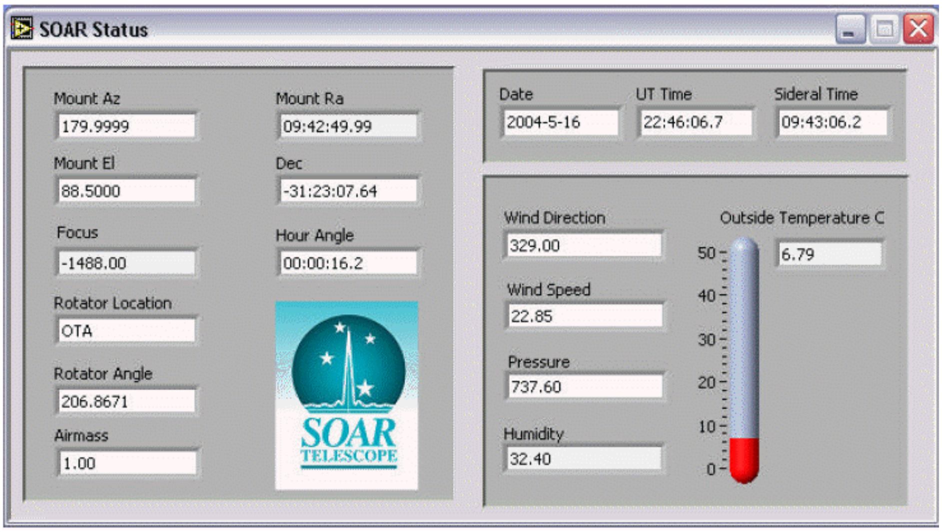


Fig. 3. A LabVIEW Datasocket client displays current status information from SOAR systems. This simple summary of essential telemetry and environmental information was "wired" in less than 20 minutes. It is easily reformatted to fit onto often crowded tactical displays.

As we discussed in Ref. 2, LabVIEW has many attractive elements for our application. Most basically, LabVIEW's Datasocket Server (Ref. 4) is a simple and efficient way to broadcast data (Fig. 3) across a network. It is ideal for streaming telemetry and environmental data. Any basic or derived LabVIEW datatype can be written to a central Datasocket Server on the SOAR network. The server allows multiple clients to read the most recent value of any number of requested fields. Broadcasting everything packed into a long string allows users to customize their status GUIs; each transfer is most efficient when <1 MB in size.

In its previous release v6.1, a LabVIEW VI running at SOAR could open a remote panel on our UNC computer desktop regardless of the underlying computer operating systems. The available functionality is expanded in v7.1, relaxing previous restrictions placed on remote-capable applications. The remote panel server allows authorized control of any front panel from another machine executing a copy of the LabVIEW runtime engine. A connection can be initiated by a LabVIEW application or a web browser. An initial burst of information sets up the remote panel, after which only "curses"-level updates are transferred to inform the client of control/indicator changes, and to inform the server of user events. The LabVIEW front panel elements are defined on the local PC, eliminating the delays of schemes such as X11 and VNC. Remote panels also add another layer of security and confidentiality by hiding the other resources and directories of the executing computer. To prepare for their observing block, several users can connect to a single panel without degrading performance. The Goodman spectrograph control system[3] is an example of a LabVIEW application that is fully compliant with remote panels. Fig. 4 shows that after the control system's panel is initialized (3-5 seconds), bandwidth drops below 32 kbps.

4. DATA TRANSFER

Our LabVIEW-coded Remote Display Tool (RDT)[2] now incorporates capabilities provided by the latest version of IMAQ Vision. We now use the commercial Kakadu JPEG 2000 codec (www.kakadusoftware.com) instead of the freeware Jasper package (www.ece.uvic.ca/~mdadams/jasper). Kakadu supports SIMD optimizations, doubling speed over Jasper. With a P4

2.2 GHz PC, we compress 500-fold a typical SOAR $4K^2$ 16-bpp image in 4.5 sec. Kakadu uses modem coding standards (C++ classes rather than C typedefs), and is supported by its author as a commercial product for $100 for academic users. RDT is coded in LabVIEW with the IMAQ library, but its executable requires only a local runtime license ($100 for academic license, Windows only). Once the IMAQ runtime license is active, the RDT can be downloaded from SOAR, and auto-installs on the user's machine. Linux or Solaris users must buy VMware (www.vmware.com, $189), under which one can run Windows hence the RDT (and Starry Night, see §5). We program with Microsoft's .NET compilers and those in the Minimalist GNU tree (www.mingw.com). We store data on the dual-processor PC with RAID array that runs the projected display under Windows XP. This machine is linked by AFS to archive facilities and to the observer's notebook computer (which typically runs IRAF under Linux).

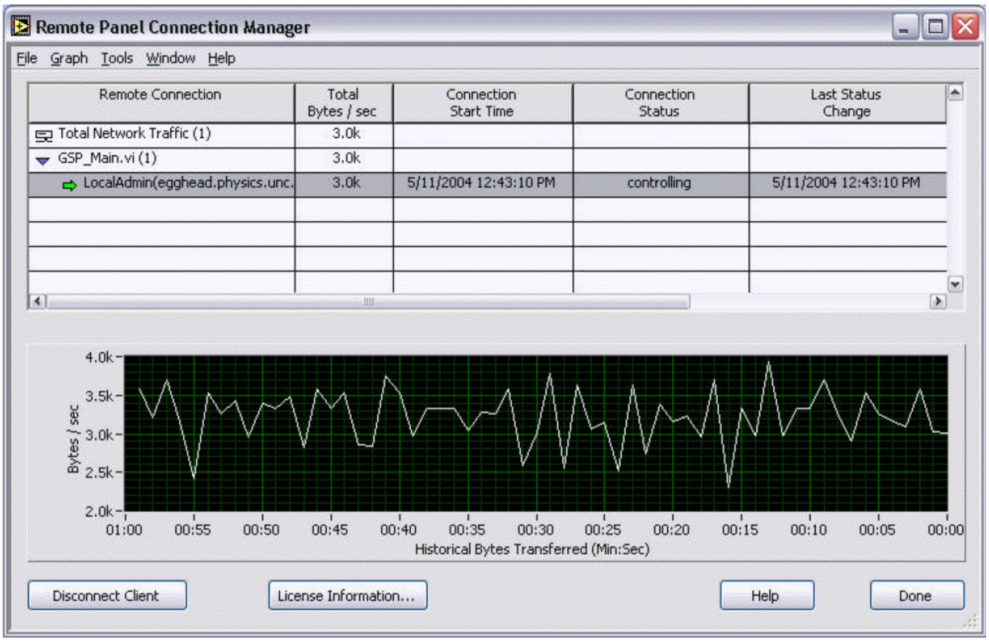


Fig. 4. The remote panel connection manager shows a client connected to the Goodman spectrograph control system.

Fig. 5 shows part of the RDT. A 300:1 lossy compressed version of the data from SOAR has drawn on it various regions of interest (ROI's). These are compressed losslessly, retrieved from SOAR automatically, and then patched into the compressed image. In idle moments, the full image is queued for lossless compression and upload; lossless compression halves astronomical image/spectral file sizes. Separate program threads run simultaneously to retrieve the queued data files. The server allows multiple client connections, with bandwidth automatically ceded to the active observer. ROS's and lossy images have higher priority than full images.

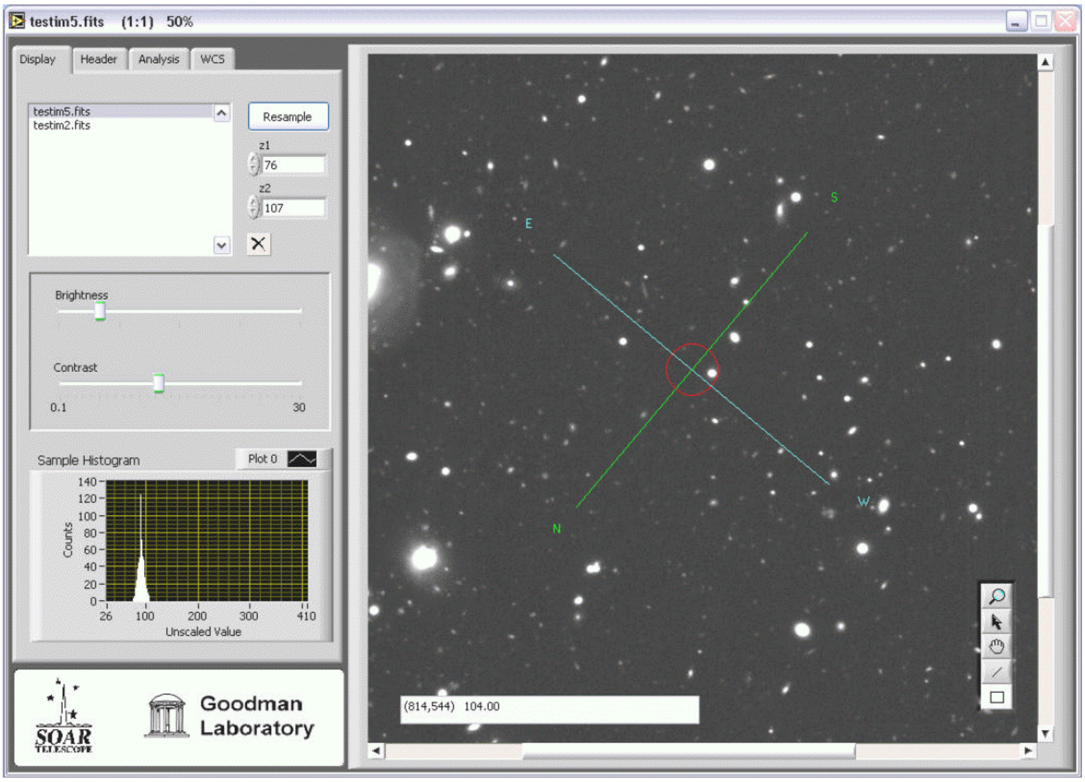


Fig. 5. Image display window of the RDT with WCS cursor. This is our interface to dynamic data compression in ROI's. Ref. 2 gives examples of JPEG 2000 compressions and their integration with the RDT. Objects can be tagged and the telescope repointed to them.

After experiments, we have tuned the bandwidth of each thread to maximize total upload speed. Little may change in our view of the SOAR control room, so much less of the low latency video bandwidth allocation is often used (e.g. Fig. 1). This gives the remote user attached by CM/DSL opportunities for simultaneous data retrieval, receipt of telescope telemetry, and instrument control. In typical use, a 768 kbps maximum VC with two upload and instrument control threads active saturates a 3 Mbps link (half these numbers for CM/DSL access). With lossless compression, a $4K^2$ image is retrieved from SOAR in 100 seconds (twice this for CM/DSL). By then, our next exposure is usually well underway. The combination of multiple threads and queued retrieval of compressed data is so effective that we do not bother to interrupt VC during data retrieval.

A remote user is allowed to repoint the telescope anywhere within its imaging field. The RDT user designates the new target, and the telescope M3 tilts to center the new target. The user can designate ROI "watch" regions fixed to a specific sky patch as defined by the data file WCS. As the telescope "dithers" the imaging field around, the ROI's from which data are uploaded translate on the detectors. This allows variations in transparency and seeing to be monitored from quick-look data during a dither sequence. Functions can be added easily with IMAQ and via the powerful Lua scripting language that has been interfaced to LabVIEW (www.citeng.com/pagesEN/products/LuaVIEW/index.html).

5. OBSERVATION PLANNING AND EXECUTION

All SOAR partners can use the Gemini telescopes, encouraging reuse of tools developed by that Observatory. Gemini users are proficient with two: the Phase I Tool (PIT) for TAC submission, and the part of the Observing Tool (OT) that successful PI's use to detail their observing program so that it can be queue executed by a Gemini support astronomer. The PIT or its look alike is also being used for NRAO's Green Bank Telescope (GBT) and for the Southern African Large Telescope (SALT), both facilities that UNC astronomers have used or plan to use.

Therefore, to present a familiar interface to SOAR users, we have customized the Gemini PIT into the SOAR Observation Planning Tool (SOPT, Fig. 6). The SOPT holds the observer's program in XML tags that are easily parsed for reuse. Unlike at Gemini, SOAR observers are available in real time, and are generally assigned half-nights well in advance. So, successful proposals do not require a 2nd (OT) stage refinement. Instead, added fields in the SOPT provide essential instrumental constraints such as slit position angle (PA), x & y sky offsets, and non-standard calibrations. The SOPT sits above any instrument configuration/planning tool provided by the SOAR instrument PI's. It uses only enough of the instrument parameters to interleave the observation into a half-night observing block.

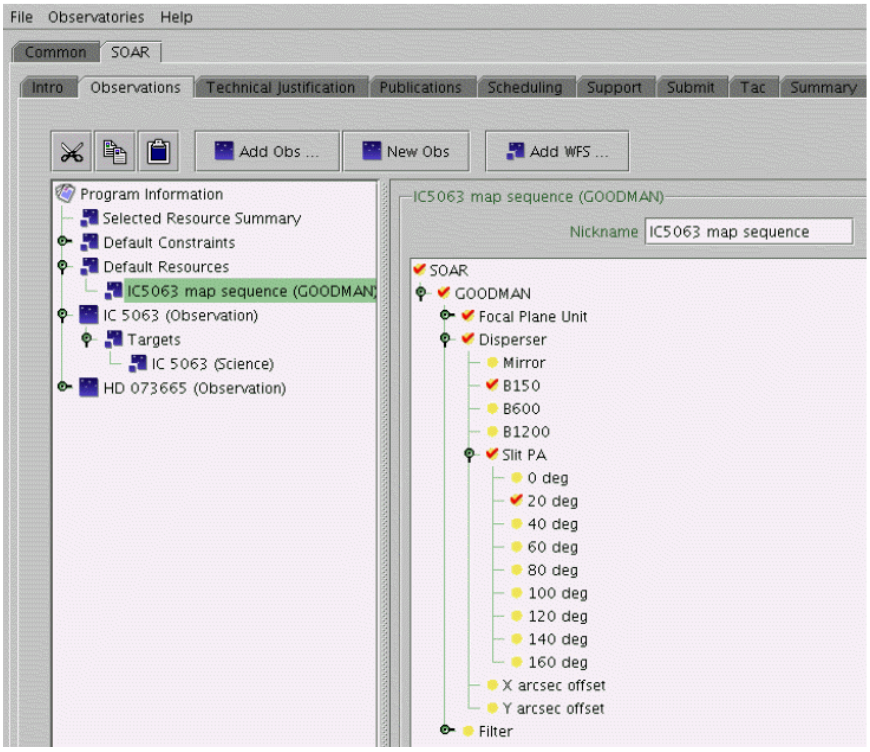


Fig. 6. The preliminary SOAR Observation Planning Tool, derived from the Gemini Phase I Tool.

SOPT XML tags drive our tactical displays. The stand-alone Culmination Plotter (CP, Fig. 7) is a Fortran/ PGPLOT program (derived from "proas" by N. Cardiel at IAS, Tenerife) that combines target and instrument observational parameters from all programs that a particular SOAR partner plans to execute during their half-night block. The CP also incorporates a processed version of the latest image from the SOAR All Sky CAmera (SASCA), together with recent seeing telemetry from the instrument guider probe and the DIMM/ MASS (a facility on the ridge between SOAR and Gemini-S). The CP shows sky brightness from moonlight, the expected seeing and sky transparency at the planned wavelength, when the optimal slit PA of each observation is accessible, and the calibration overhead.

Our main tactical display is a C++ plug-in for the Starry Night (SN) planetarium program. We prefer SN Pro 3.12 to the latest release 5. Our plug-in reads the XML file and generates target arcs that span the exposure. The tracks are colored according to the SOAR instrument. For spectral observations, track regions without the optimal slit PA are dimmed. The background starry sky is seen through a translucent overlay that depicts the relative attenuation of clouds. Sky cover comes from the SASCA images. Each is filtered to remove stars, then differenced with a past SASCA image of the clear and moonless sky obtained at the same sidereal time, and finally smoothed lightly to accentuate clouds. Fig. 8 is an example of the final display, on a night with cirrus. Current extinction is established at B and R wavelengths, then is scaled to observing wavelength and plotted in the CP to show extinction trend with air-mass near the meridian.

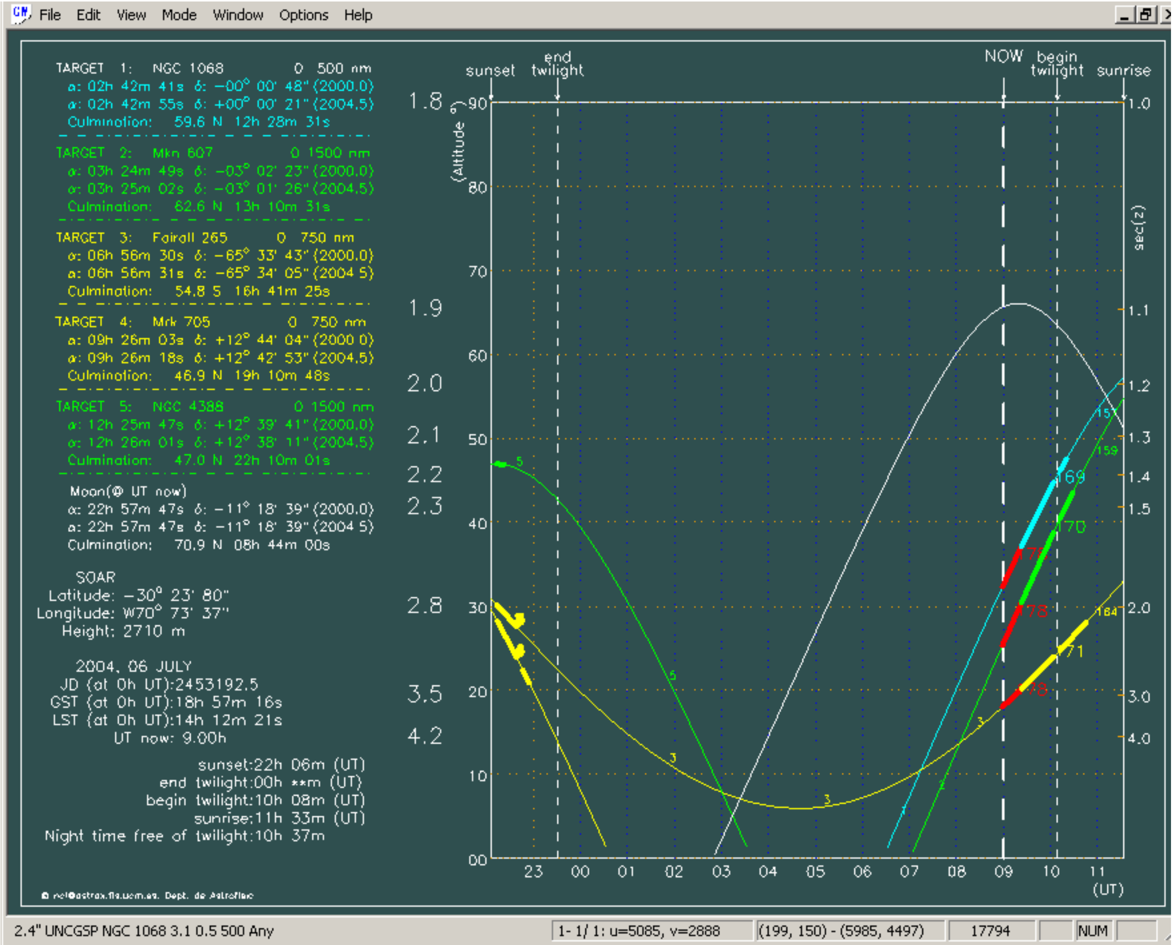


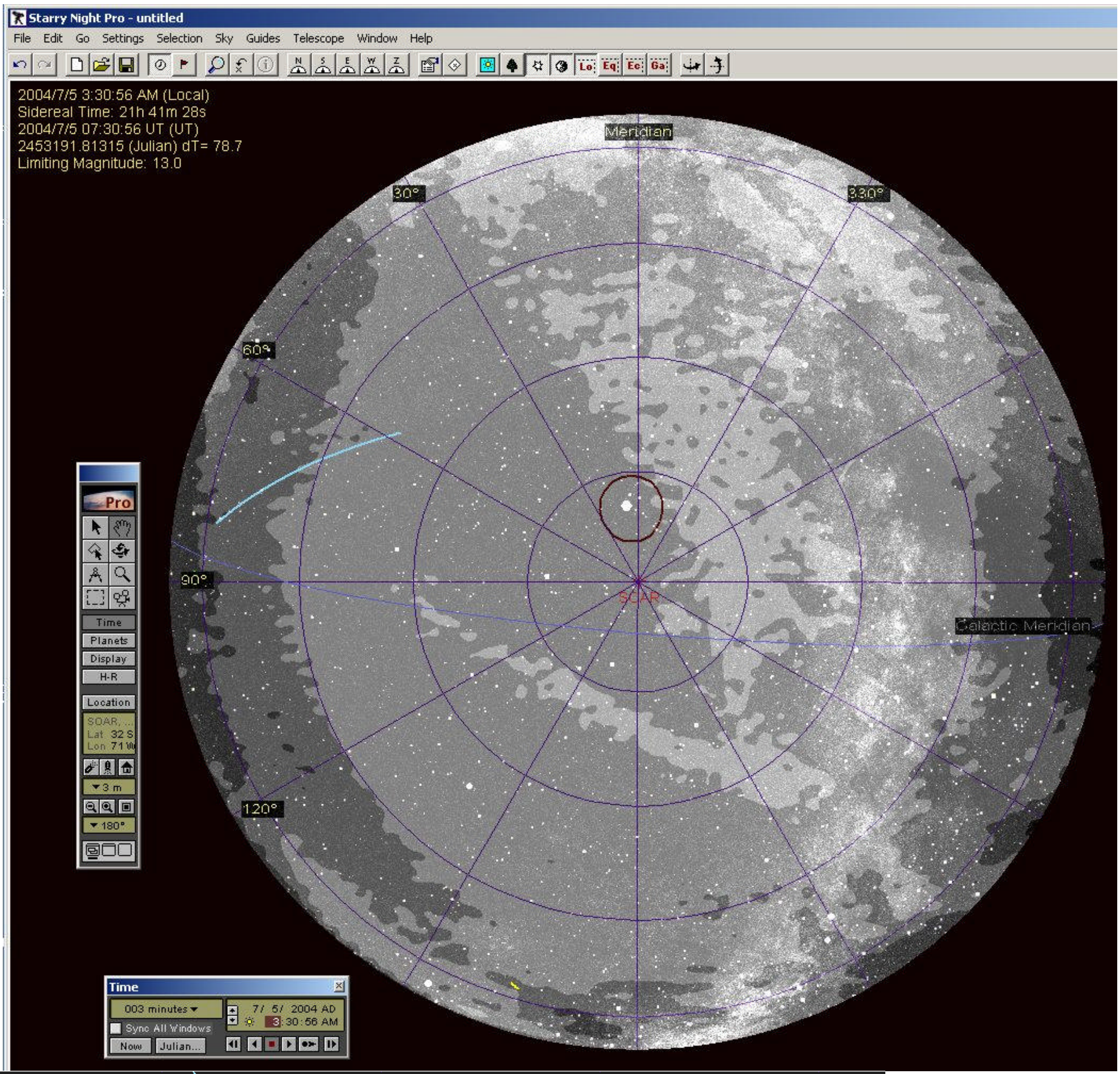
Fig. 7. Snapshot of the dynamic Culmination Plotter. Target tracks are shown, with at left the anticipated seeing scaled from the current DIMM/ MASS reading to the wavelength and zenith angle of the selected target. Requested exposures are red, and thick lines show near-term intervals where the parallactic angle is suitable for the slit PA.

6. SUMMARY

Our experiments have encouraged UNC astronomers to use SOAR remotely from the start of science operations in 2Q 2005. Astronomers at Michigan State University have constructed a similar remote observing facility, with the same intent. Brazilian colleagues are dispersed, but some institutions have acquired VC equipment and connect to SOAR routinely. NOAO users are also dispersed, but growth in I2-based VC will explode as travel costs climb and resources for astronomers diminish. So, we expect that in a couple of years most people will use SOAR remotely. By then the tools in this paper will be quaint curiosities, and the SOAR control room will be part of many video walls.

REFERENCES

1. G. Cecil, "First Generation Instruments for the SOAR Telescope", Optical and IR Telescope Instrumentation and Detectors, Masanori Iye & Alan F. Moorwood eds., Proceedings of the SPIE, Volume 4008, pp. 83-93, SPIE, Bellingham WA, 2000
2. G. Cecil, A. Crain, G. Schumacher, "Remote Use of the SOAR 4.25m Telescope", Advanced Global Communication Technologies for Astronomy II, edited by Kibrick, Robert I., Proceedings of the SPIE, Volume 4845, pp. 72-79, SPIE, Bellingham WA, 2002
3. J. A. Crain, J.C. Clemens, M. Bayliss, "The Goodman spectrograph control system", Advanced Software, Control, and Communication Systems for Astronomy, Hilton Lewis & Gianni Raffi eds., Proceedings of the SPIE, Volume 5496, pp. X-X, SPIE, Bellingham WA, 2004
4. J. Travis, Internet Applications in Lab VIEW, Chapter 5, Prentice Hall, New York, 2000



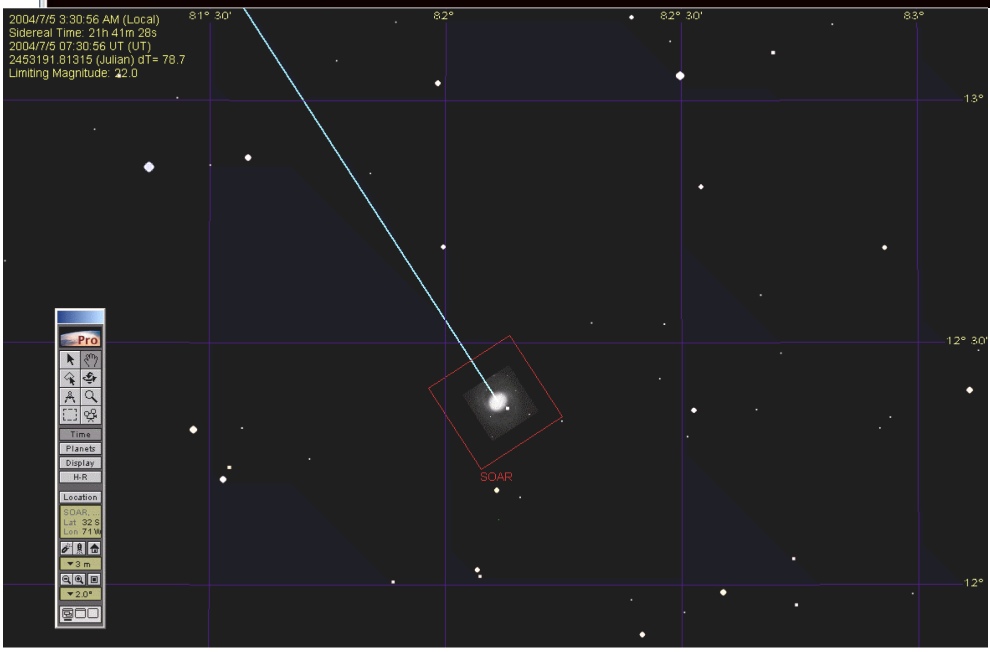


Fig. 8. (Above) All sky view at SOAR, showing color coded (by instrument) target tracks during nominal exposures, and SASCA all sky image (in this case with considerable cirrus) that is updated every 2 minutes. Here the telescope is pointed at the zenith, near the moon. The circle around the moon shows an exclusion region of bright sky, scaled for the current observation wavelength. (Left) zoomed to show target acquisition image, downloaded from the DSS by the SN interface. Images from SOAR instruments can also be inserted into the SN database as they are acquired.