VLA Electronics Memo 242

May 2, 2002

1 Introduction

This paper is in partial fulfillment of course requirements for the New Mexico Institute of Mining and Technology Department of Electrical Engineering's Senior Design course. This is a detailed description of the work accomplished by Gerald Bivens, Sam Field, and Brian Rajala on the National Radio Astronomy Observatory's Small Radio Telescope project between August 2001 and May 2002.

1.1 **NMT Senior Design Course**

As part of its requirements for graduation, the Electrical Engineering Department at New Mexico Tech offers a two-semester design course. At the beginning of the course, seniors in the department are offered a number of projects by outside entities representing a wide variety of public and private enterprises. Students are placed in groups of two to four members based on their project selections. Each team is responsible for meeting with their customer to draft a statement of work outlining the customer's requirements for the project. The rest of the year is spent working to meet customer demands. In addition to work for the customer, regular presentations and progress reports are required. This work culminates in a presentation of group achievements to Electrical Engineering faculty and the department's corporate advisory board, as well as written documentation of the project. Grades are based on customer satisfaction, regular written and oral communication, and overall team performance.

1.2 The National Radio Astronomy Observatory

Among the customers offering projects was the National Radio Astronomy Observatory (NRAO). The NRAO is a publicly funded research facility operated by Associated Universities Incorporated (AUI) for the National Science Foundation (NSF). Based in Charlottesville, Virginia, NRAO operates a number of world-class radio telescopes

including the Very Large Array (VLA) located west of Socorro, New Mexico. Composed of 27 antennas in the San Augustin plains, the VLA is a one of a kind instrument used by scientists from around the world to conduct cutting edge research. The VLA has a visitors center, which NRAO is currently in the process of upgrading. One of the plans in the expansion is to put a small, single dish radio telescope in the Visitor Center where the public can access it. The radio telescope would be one of the first stops on the self guided tour and would educate people about radio astronomy so that they could get the most out of their visit to the VLA.

1.3 The Small Radio Telescope

The project offered by NRAO involved the adaptation of an existing radio telescope kit intended for students and amateur astronomers for use by the public at the VLA Visitors Center. The Small Radio Telescope (SRT) kit was developed by the Massachusetts Institute of Technology (MIT) as a fully functional radio telescope and is sold for use primarily by universities and amateur astronomers. The kit consists of a commercially available satellite dish, originally made for satellite television systems, along with a custom azimuth/elevation drive, L-band receiver, and a controller which allows the telescope to be interfaced with a PC. The control software is furnished as open source Java code and provides full control of the SRT through a simple graphical user interface (GUI).

The SRT (Figure 1.3.1) collects data from the universe in the radio part of the electromagnetic spectrum. The radio spectrum ranges from 1mm to 30 meters. Data can be collected in both the day and night. The emissions that are measured by the SRT come from the astronomical objects that are in the universe. The radio telescope uses a large parabolic metal dish to reflect radio waves to the sub-reflector. The sub-reflector then directs the radiation to the feed at the center of the reflector. Then the signal is amplified through the receiver. A computer then processes the amplified radio signal. The SRT will be tracking, for example, the Sun, Cygnus A, and Cass A., which are strong radio sources.

Figure 1.3.1 Small Radio Telescope on top of Workman Center

NRAO ordered an SRT kit with the intention of installing it at the VLA Visitors Center for use by the public as an interactive tutorial on radio astronomy. As furnished by MIT, the kit is not suitable for this application for a number of reasons. First, the control software is not intuitive and requires a significant amount of time to learn. Second, a mouse and keyboard are needed to run the telescope, both of which are subject to theft and damage and allow too much access to the computer running the telescope. Third, the software is intended for users with significant knowledge of radio astronomy, and is therefore of little value in educating the general public. Therefore, our project was to modify the kit to make it suitable for NRAO's needs. This involved making it easy for the public to use. The intent of the project is to demonstrate the functional operation of a radio telescope and provide a tutorial on radio astronomy for the public.

2   Overview of Radio Astronomy Project

2.1 Customer requirements

In order to find out what the project was all about we made contact with Clint Janes, Electronics Division Head and Robyn Harrison, Educational Liaison for NRAO. We first met with Robyn Harrison and discussed NRAO's needs. We found that we would be furnished with a kit to build a radio telescope, a development computer, and access to NRAO facilities. We would have to manipulate the software to track an assortment of astronomical objects and display telescope data in a manner that is both educational and easy to understand for the general public. We would have to implement an interface that would be foolproof and easy to use. The interface had to control the telescope without a keyboard or mouse, but would still allow public interaction. It was suggested that this be done with a touchscreen. The top priority of the entire project was to educate the public about radio astronomy.

The Project budget was briefly discussed and we were told that a distinct ceiling was not set, but all expenses must be approved by the NRAO. This would also include installation of "things like support piers, conduits, [and] electrical" (see e-mail Appendix-A page 63).

2.2 Assignment of Work

A clear idea for this open-ended project was obtained when we presented our initial ideas attending a meeting with Visitor Center Committee. From this meeting, we were also able to finalize the Statement Of Work contract. After outlining the customer's requirements for the SRT Project, we had to decide how to break up the project among the team. The logical divisions of work seemed to be in the areas of control software, touchscreen interface, educational tutorials and final installation design. In addition, some tasks were determined to be immediate needs that the entire group would address. These included:

- Set up development computer with network capabilities.

- Decide on control software options.

- Download NRAO web links and VLA Weather Station program in design.

- Acquire the Java compiler the open source Java code for SRT tracking software.

- Acquire Microsoft Office for educational slideshow presentations in PowerPoint.

- Obtain a touchscreen for input and control.

- Communicate vehemently with the vendors to remind them to send the SRT kit.

- Obtain permission for testing location.

  Viable locations discussed and debated.

Once we had a breakdown of the individual tasks we could assign them according to our levels of expertise in each area. Sam would work on the Java software, Brian would work on the touchscreen interface, and Gerald would be responsible for developing educational material and coordinating installation at the VLA.

3 Discussion of Individual and Group Accomplishments

After initial contact with our client, we devised methods of putting together the tasks that the project entailed. The first task was to break up the work among the group members. This was accomplished by evaluating our strengths and weaknesses. In doing this we tried to consider each group member's strengths. Sometimes our group was lacking any knowledge of a subject, but we plunged into research of the topic anyway, and found some valuable information. The following sections are our individual personal accountings of the SRT project, followed by a section describing work that performed as a group.

3.1 Gerald

From the start of this Senior Design project my tasks fell under two main categories: communication and education. It seemed that more effort went into communication with people to pool information and to organize the many tasks that would bring the SRT Project to completion. Many people were involved in completing this project and gave it a professional polished look. The education aspect was certainly a challenge, as I had no prior experience with radio or any other astronomy. The idea for educational tutorials from PowerPoint slides had its basis in many courses I have taken in my undergraduate studies at NMT.

Initial communication and coordinating efforts started with some personal contacts I had at Tech's Physical-Plant. I took the task of finding out about putting the antenna on a roof at Tech. We thought our hardware was due to arrive soon and getting an area laid out before the equipment arrived would be a good idea. At Tech's Physical Plant, I was put in touch with the architect for Tech. Together we surveyed the roof of the Workman building for installation of the SRT and discussed possible alternatives. We found we could run the cables down through the existing conduit. We checked the blueprints for access points for the cables. Since the Workman building was designed for experiments

to be mounted on top of it along with penetrations for power, control and data cables to various points in the building, the Workman roof seemed to be perfect. Roof mounting would avoid obstacles from the SRT looking at the sky. Another reason for roof-mounting was to reduce the possibilities of tampering with the dish since locked doors control the roof access.

We went through some more brainstorming of ideas with our project advisor and supervisor on topics such as, permissions for NRAO to have the antenna on Workman or another place on Tech property, liabilities, other design planning, other politics and even other possible sites like Etscorn Observatory and my house. We needed to find out if we would need administrative permission (Brown Hall), or if we would be infringing on any positions of Union workers from the P-Plant or other government workers and whether we would need work orders to complete our installation. Further tasks were assigned and

I got to find out about mechanical, cabling, and power requirements.
When we finally obtained permission for the roof-mounting, we had to decide whether or not to order the base for it. I also investigated the other technical aspects from data sheets for the SRT. From my literature search, I decided we did not need a base as the antenna would fit over the existing stanchion as in Figure 3.1.1.
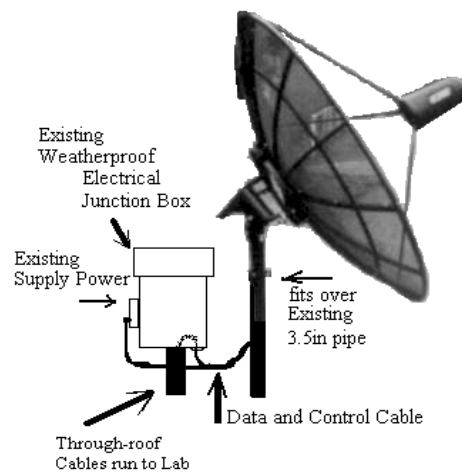

Figure 3.1.1. Concept Design for Mounting SRT

A literature search confirmed that since the parabolic dish is of a metal mesh construction, wind loading would not be a problem. The architect's only concern was for the dish to be secure. He was assured that it would be, and as a follow-up, he was contacted again when the dish was installed to confirm it was a secure installation.

Since the antenna was to be controlled from a lab on the second floor of the Workman building via a personal computer, about a hundred feet of control and signal cables had to be run between the antenna and the lab. It was necessary to find out which labs the cables would go through and for access to conduits on the third floor and obtain permission to run the cable in those existing conduits. One professor on the third floor would not allow access to the conduit run in his lab (due to sensitivity of his experiments), so an alternative route was needed and permission for routing the cable there was obtained. The Closed Circuit TV video cable was run through a different set of conduits and permission to run that cable was also obtained. I devised a bracket assembly for temporary mounting of the camera to the roof stanchions and hooked up a power cord.
Based on how the project goals were to be divided up, I went ahead and made a Gant chart to be approved by everyone. From this further division of tasks I was to work on the watchdog, which was required to restart the system in the event of a power failure. I had no idea how to find a watchdog, and after extensive literature searches and interviewing the network system administrator, I found out how we could restart our system without human interaction and without additional costs.

For the responsibility of education I started to educate myself in the basics of radio astronomy from websites and other reference material recommended by Robyn Harrison to develop the instructional displays. Preliminary ideas, like Physics and Radio Astronomy, for the tutorials were initiated and in the second semester I started compiling literature search information. I finally decided on three slide shows for tutorials and one slideshow for the project itself. The largest slide show is The Science of Radio Astronomy, which tells about some of the complex topics of radio astronomy and breaks them down to a basic high school grade level. How the SRT Works is the next largest

slide show, which describes the major parts and pieces of this small radio telescope. The Tracking slide show, which runs automatically and gives time for the antenna to start tracking a source before the viewer gets bored, tells of what the SRT is doing and what will be seen. The final slide show, The SRT Project, was developed for presentations.
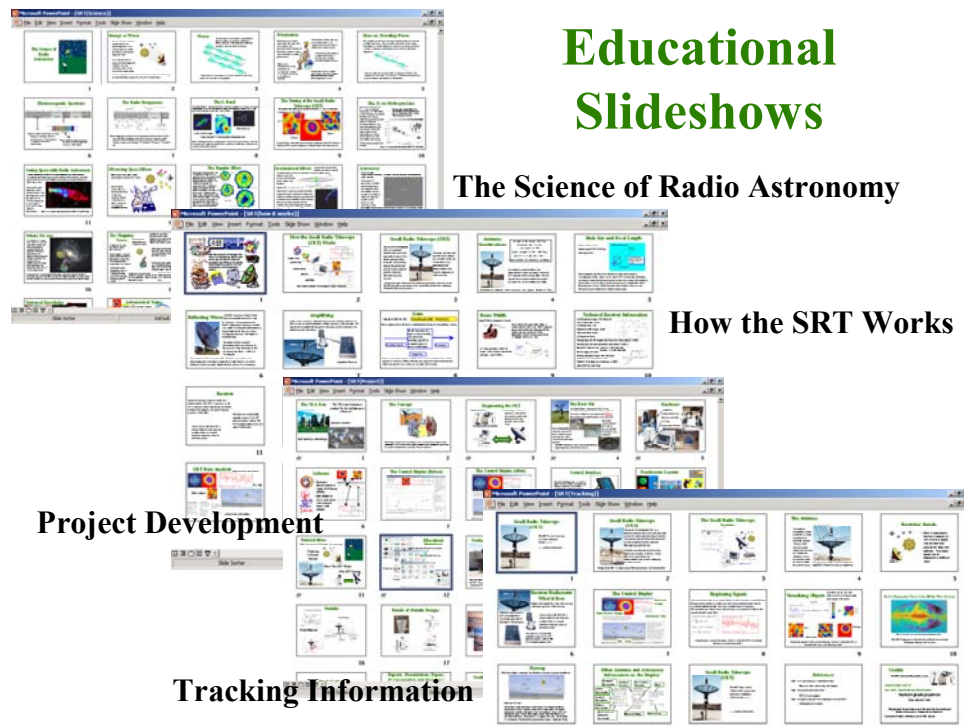

Figure 3.1. 1 Tutorial Slide shows

In addition, because of my background as an electrician (please see resume in appendix), I designed and submitted for approval the power and signal conduit runs for cables run inside of conduit when the entire project is moved for use at the VLA Visitor's building (Figures 3.1.3. and 3.1.4.). Final design approval from VLA personnel and the NRAO safety officer was needed before construction could begin.
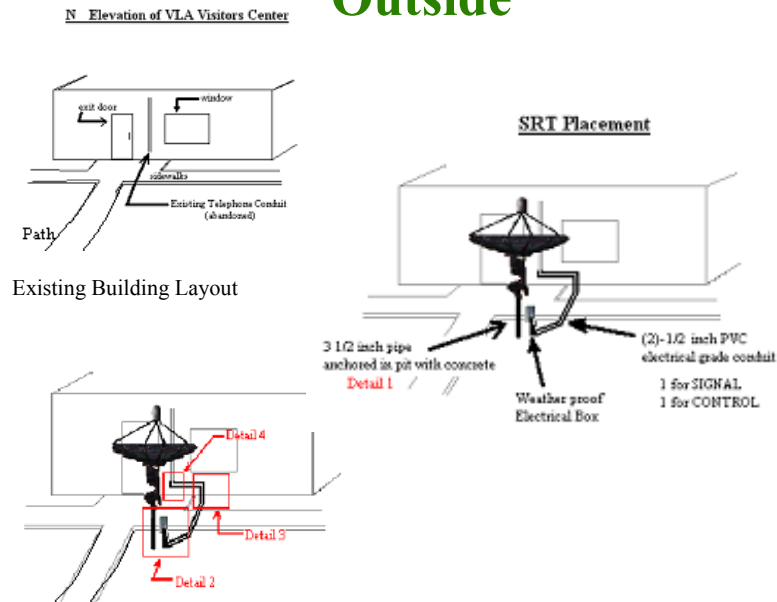
Outside

Existing Building Layout

Figure 3.1. 2 Preliminary Installation

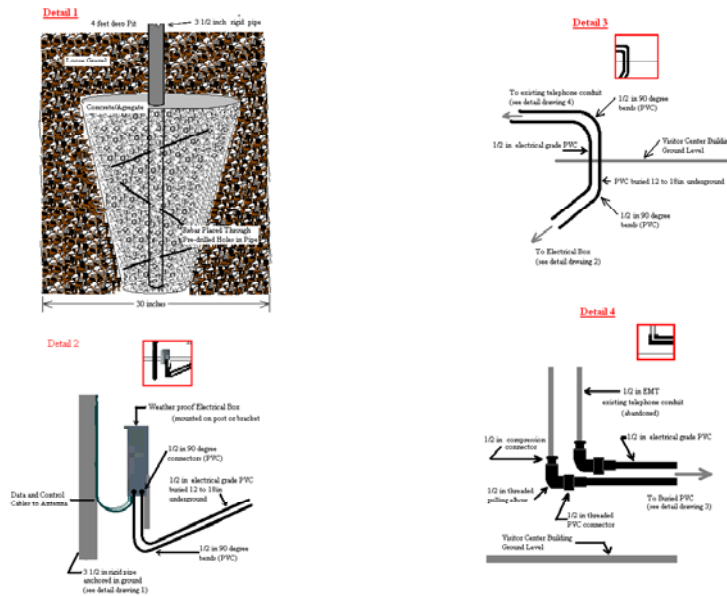# Details of Outside Designs

Figure 3.1. 3 Details of Installation

Coordination efforts with the key personnel for the final SRT installation had a few issues that had to be resolved. While the concept designs were generally accepted (as well as the preliminary parts lists), by the time February rolled around several e-mails were received regarding some confusion in these installation plans for the SRT. Personal contact with the lead people overseeing the different construction phases the SRT Project installation was needed "to get everyone on the same page." I had to address specification issues like location, materials, parts, installation design, grounding concerns, lightning protection, and a fence for protection. Talking personally to the Grounds Projects Coordinator, the Head Electrical Engineer and the Lead Electrician, seemed to clear up the idea of the entire project. This saved a lot of time and confusion in emails, phone calls, and inter-department memos. Next, my conceptual design for the housing cabinet for touchscreen and monitor and computer and controller was submitted for approval and revisions (Figure 3.1.5.). The Safety officer for the VLA, Jon Spargo, was contacted, to address his concerns on the SRT project. He was assured that the National Electric Code regulations for power and signal voltages were observed. For warehouse parts that might be needed at the site we had to have authorization for dispersion, so I contacted appropriate personnel for those authorizations. In the beginning of March, I came up with a physical design for implementing the lightning protection devices. I consulted with Communications installation technician Pete Martinez of the Information Services Department of NMT about lightning protection. For the end of this project, I will oversee the final installation of this lightning protection equipment that was not a part of our original statement of work.

Figure 3.1. 4 Visitor Center Kiosk Concept

3.2 Sam

My work on the SRT project focused on developing software which would control the telescope and provide a display of useful information for users. This is a detailed description of the work I accomplished between August 2001 and May 2002.

While we were in the initial stages of determining what needed to be done and how to split up the work, one of the tasks that came up was the implementation of some sort of control/data processing/data display software that would run the dish and display the information it gathered in a manner suitable for educating the public about radio astronomy. There were a number of options available, including software such as TheSky by Software Bisque. TheSky would have provided a very nice graphical user interface (GUI) but would have taken work to interface with the SRT. We decided early on to use the software that MIT ships with SRT.

This software is shipped in the form of Java code which must be compiled by the user to run the telescope. We had a number of good reasons to use this software. First, it would save us the work of figuring out how to calculate azimuth and elevation coordinates of sources, how to point the telescope, and how to process information coming in from the receiver. In addition, the fact that the software was open-source made it very easy to modify to suit NRAO's needs. Thus, the decision was made to use SRT's existing control software. I volunteered to do the programming because I had the most programming experience in the group, having written much of the code for my junior design robot. Still, I had not done any Java programming or worked with a program of this magnitude before.

The SRT control software consists of about 5400 lines of code divided into 12 classes. Their names and functions are given in Table 3.2.1.

Class Name	Primary Function
Cat	parse srt catalog file
checkey	watch mouse and keyboard
disp	define functions for graphics and text
geom	compute az/el pointing coordinates
global	store and provide access to global variables
map	contour 25 point map
outfile	write output file
plots	plot skymap, spectra, and power vs time displays
procs	coordinate procedures in other classes
sport	communicate with controller via serial port
Srt	main class: initialize software and telescope
time	calculate time in all the various formats SRT uses

Table 3.2.1: SRT Classes and Their Functions

When the SRT program starts, it begins in the class named srt. This class initializes all variables and runs the telescope to its mechanical stops so that it has a base position (referred to by the software as the stow point). This is necessary because the azimuth and elevation drives do not have absolute encoders. Every time the software is shut down the computer forgets where the dish is pointed. After finding the stow position, it starts an endless while loop which hands over control of the dish to other classes. At this point, the user is free to issue commands using a combination of control buttons at the top of the screen and a text input box at the bottom. Sources are selected by clicking on them on the skymap. Figure 3.2.1 shows the SRT control display in its original configuration.
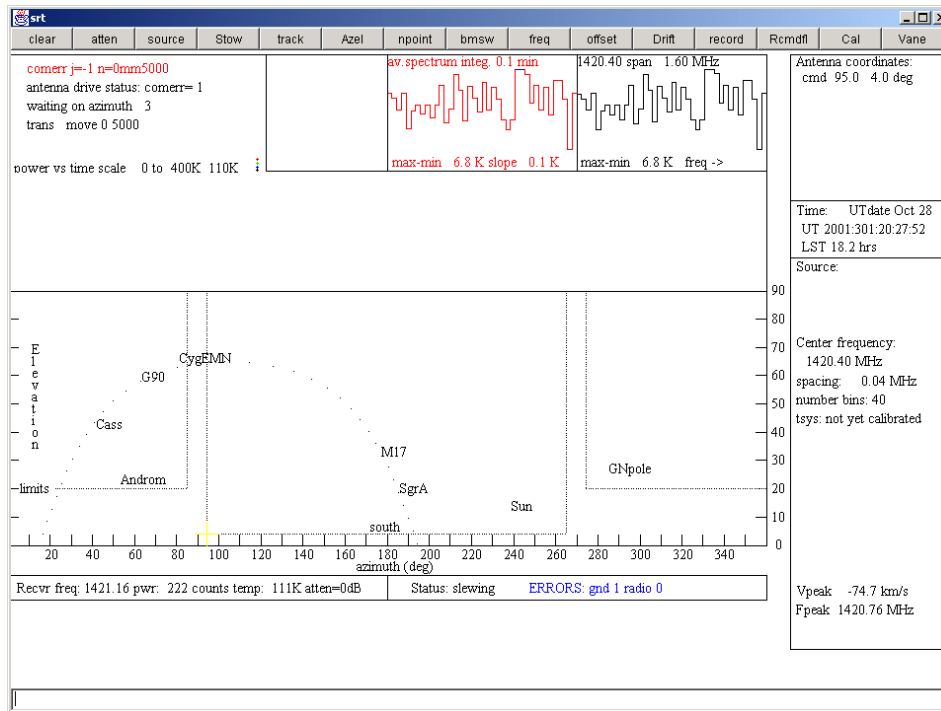
Figure 3.2.2 Original SRT Control Panel

There were a number of changes that had to be made to the software. First and foremost, the display as it arrives is fairly confusing for people with a technical background, let alone people with little or no knowledge about astronomy. I had to read through the manual a few times to understand how to use the display to control the SRT. It is unreasonable to expect visitors to read 15 pages of instructions before using the SRT, so the display had to be changed. Also, NRAO specified a "bulletproof" system which would be safe to leave in the hands of unsupervised visitors. This ruled out leaving the mouse and keyboard accessible to the public. Input would be accomplished via a touchscreen, so the software had to be modified to allow this.

Before I could modify the software, I had to learn how it worked. The code had minimal documentation, something on the order of one useful comment every few hundred lines, and many of the variables did not have names reflecting their use. I spent over a week reading through the program and marking the parts I could recognize before modifying any of the code.

My first modifications were to the display. The display is drawn by the class procs, which calls methods defined in plots. Plots contains methods for drawing the skymap, the spectrum plots, and the power vs time graph. I started by temporarily removing all of the display elements. This proved to be a time consuming task, as numerous classes contribute to the display. Tracking down all of the drawn elements and commenting them out of the code took many hours.

Starting with a clean slate, I began work on the spectrum plots, specifically working to make them movable and scalable to fit our needs. This work began in October 2001 and continued into March 2002. The SRT program generates two spectrum plots, as shown in Figure 3.3.1. The one on the right is redrawn with every sweep of the receiver across the observing band. The one on the left is the average over time of the individual sweeps. We chose to include the integrating plot in the final display, for the reason that it is less susceptible to noise and provides a cleaner spectrum. To move the plot around on the screen, the programmer has only to specify the upper left and lower right corners of the plot. Either of the plots can be turned on or off using a switch in procs, which calls the method that draws the spectra.

During this time I also worked on the skymap, changing it in much the same way as the spectra plots. The skymap is now easy to move and resize by setting the upper left and lower right corners in three classes. The outlines and mechanical limit lines are drawn in plots, the sources are drawn in geom, and sport draws the crosshairs which indicate the antenna position.

I encountered several scaling problems in altering the spectra and skymap, mostly due to the fact that SRT uses methods in many classes to draw these objects. The drawing commands pass through a number of scaling routines before actually being drawn, and I had to keep close track of where scaling happened to get the items to display properly.

The second phase of modifying the display involved deciding where to put all of the display elements, as well as making them clearer and more attractive than in the original.

With artistic direction from Gerald and Brian, I placed the skymap in the lower left corner of the display, and the spectrum in the upper right. In addition, we superimposed the skymap on a picture of the VLA landscape so that zero degrees elevation lies along the horizon. To further clarify the function of the skymap, I wrote an explanation which is to the right of the image. A final touch was to replace the crosshairs SRT uses to denote the active source with a small transparent background GIF image. When the sun is being tracked, an image of the sun appears on the skymap. For other sources, an image of a star marks the source in the sky. I also wrote an explanation of the spectrum, and placed information on parameters such as source coordinates, telescope coordinates, receiver frequency, and time on the display. In addition, there are two pictures of the active source in the upper left corner of the display. One is produced using SRT's mapping function, and the other is produced by the VLA. The map function on SRT is very impressive, and we would have liked to have made it available to the public, but it takes a very long time, so the image shown on the display is from a previously produced file. The main purpose of these two images is to show visitors the quality of the work taking place at the VLA.

Figure 3.2.2 is a screenshot of the new display panel as it would look tracking the sun. It shows all of the elements mentioned above.
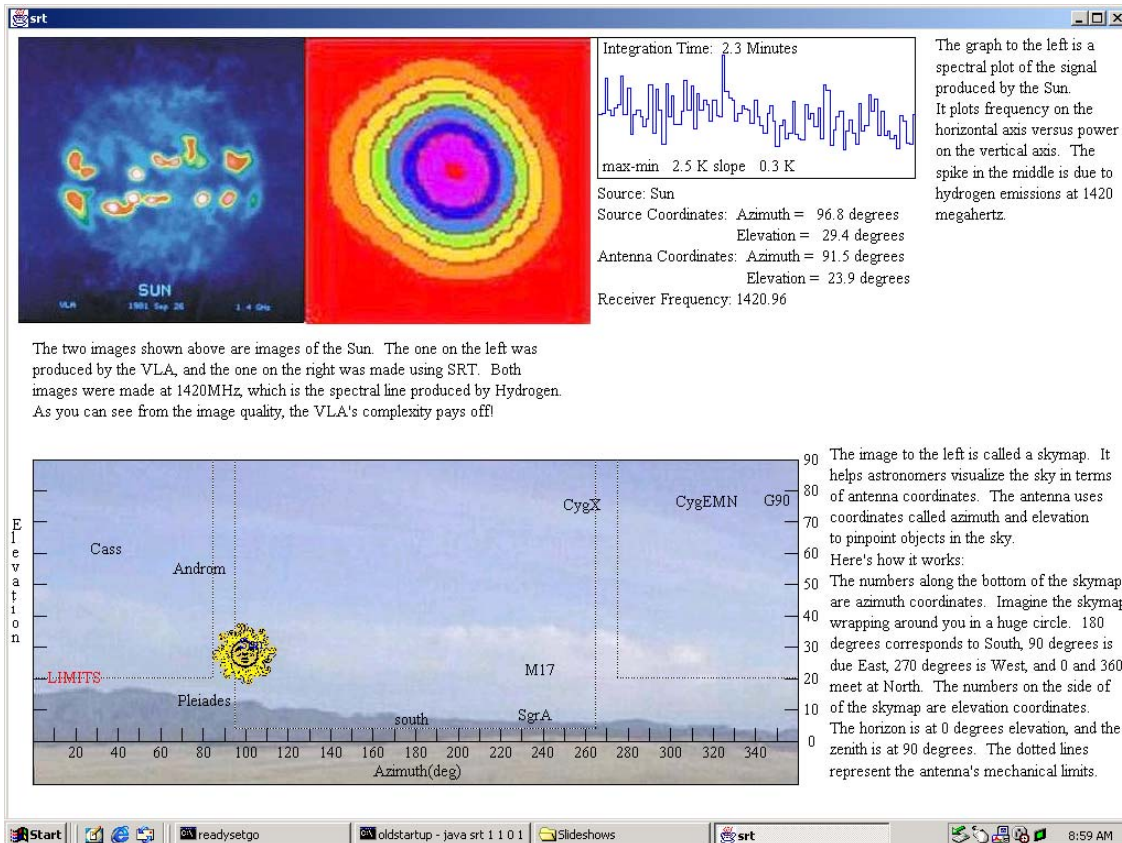
Integration Time: 2.3 Minutes

max-min 2.5 K slope 0.3 K

Source: Sun
Source Coordinates: Azimuth = 96.8 degrees
                    Elevation = 29.4 degrees
Antenna Coordinates: Azimuth = 91.5 degrees
                     Elevation = 23.9 degrees
Receiver Frequency: 1420.96

The graph to the left is a spectral plot of the signal produced by the Sun. It plots frequency on the horizontal axis versus power on the vertical axis. The spike in the middle is due to hydrogen emissions at 1420 megahertz.

SUN

The two images shown above are images of the Sun. The one on the left was produced by the VLA, and the one on the right was made using SRT. Both images were made at 1420MHz, which is the spectral line produced by Hydrogen. As you can see from the image quality, the VLA's complexity pays off!

The image to the left is called a skymap. It helps astronomers visualize the sky in terms of antenna coordinates. The antenna uses coordinates called azimuth and elevation to pinpoint objects in the sky. Here's how it works: The numbers along the bottom of the skymap are azimuth coordinates. Imagine the skymap wrapping around you in a huge circle. 180 degrees corresponds to South, 90 degrees is due East, 270 degrees is West, and 0 and 360 meet at North. The numbers on the side of the skymap are elevation coordinates. The horizon is at 0 degrees elevation, and the zenith is at 90 degrees. The dotted lines represent the antenna's mechanical limits.

Figure 3.2.2 Modified SRT Display Panel

My other primary modification to the software involved controlling it. Without a mouse and keyboard, SRT would be useless, so the software has to interface with the touchscreen. There are a number of ways of doing this. The best would be to implement a driver which would interface the program directly with the touchscreen. Brian and I investigated this possibility by speaking to Pat Van Buskirk, one of NRAO's programmers. She referred us to another programmer who did not have time to help us. We looked in a book and also checked a few internet references and decided against trying to write a driver for the touchscreen, mainly due to time constraints. Also, the touchscreen that Brian had selected came equipped with some powerful software which lets it emulate sequences of keystrokes, mouse movements, and other functions. He had set it up to run the software through a DOS prompt for testing, so we decided to continue along that route.

As it arrived, the SRT software uses three command line arguments. These serve as switches for az/el drive simulation, receiver simulation, and maintenance mode. To keep things as simple as possible, we decided to simply add another command line argument which would specify the source. This works with the SRT catalog file so that the number entered in the fourth argument corresponds to the order of the desired source in the catalog file. This proved to be a quick way to select sources using the touchscreen. The rest of the necessary commands are hard coded. When the touchscreen starts the program, it passes the desired source through the fourth command line argument. The software takes note of this and goes about its routine of moving the dish to the stow position. I had to add a mechanism to wait while the dish moves, due to the fact that the software moves much faster than the dish. The original software depends on the user waiting until the dish stows before making commands. Adding this waiting mechanism turned out to be a lengthy process, but it is in place. Once the dish is stowed, commands are issued within the program to select the previously noted source and begin tracking. There are a few other settings that occur, but this is the basic routine.

While I would by no means claim ownership of the new version of the SRT software, there are some new functions that I implemented that did not exist in the old version. The routine that waits until the dish stows before issuing commands did not exist. It was also fairly difficult to implement due to the lack of information on dish status available within the program. This is because the two Basic Stamp microcontrollers in the SRT control module handle the most basic drive tasks. Interfacing the program with the touchscreen is another accomplishment I made. While very simple, this ability was also not present in the original software. A third contribution I made to the program is a method for drawing images. While it sounds simple, I had never used images in a program before, and I had to figure out how to do it. I found Google's usenet archives invaluable for this, along with the many other aspects of working with this program that I did not understand at the start of the project. Also, I did my best to add comments to the code, hopefully clearing it up a bit for future work. Commenting (and coding in general) became much easier one night in February when Dr. Stephen Bruder walked into the lab and asked why I was using Wordpad. He suggested downloading a Java Integrated Development Environment

(IDE). I downloaded and installed the RealJ IDE that night and life immediately became much easier. I did not use many of its features, but the color coding in RealJ helped immensely. My version of the code can be found on the accompanying CD.

In summary, I would describe my work as reshaping the visible parts of the program for NRAO, rather than rebuilding it in any way. The things I would certainly not claim in the program are all of the major program functions such as calculating source coordinates, calculating dish coordinates, low level dish control, receiver control, data processing, and time calculations. I also did not do any work on the serial interface the program uses.

While the program consumed the bulk of my time on this project, I had other tasks. One of these was figuring out how to update the computer clock automatically and accurately, as well as determining the dish's physical location. This is necessary because of the manner in which the software calculates source coordinates. The coordinates are specified in the catalog file in right ascension/declination form, and to transform these into SRT's native azimuth/elevation coordinates, accurate knowledge of current time is absolutely necessary. In addition, it is necessary to specify the coordinates of the telescope's location on earth. With knowledge of its position, both physically and temporally, the telescope can figure out where to point. Physical location would be easy to determine. A GPS reading at the dish location will be more than accurate enough to point the dish.

Deciding how to update the clock required much more work. One option was a radio receiver which would plug into the computer's serial port and update the clock using the signal broadcast by the National Institute of Standards and Technology (NIST) in Fort Collins, Colorado. I ruled this out due to the fact that we could not test it. The receiver was specified for use in wood frame buildings, and it seemed highly unlikely that it would work in our lab in Workman. Another option was software which would log in to one of NIST's time servers over the internet and update the clock. This was attractive because it would be cheap and would require no additional hardware. NIST distributes a

very nice program for free which seemed to suit our needs perfectly. It could be set to update the clock as often as once per hour, more than enough to keep SRT pointed accurately. This did not work, however, due to the EE Department's firewall. I explored many options, downloading and testing numerous freeware and shareware internet time update programs. None of them worked through the firewall. I checked with Chris Pauli and found that changing the firewall settings was not an option. One thing I noticed about the NIST software was that it used TCP port 13, with no provision for changing this setting. I downloaded the source code for the program and changed it to use port 80, but found that this would not work. The time server the program accesses only listens to port 13. As a last resort I talked to James Robnett, one of NRAO's computer experts. He told me that NRAO maintains two time servers on its network for the specific purpose of updating PC and workstation clocks. He said that connecting our PC, which runs Windows 2000, would be no trouble at all once it was on the NRAO network. The problem was solved, but I spent about two weeks on it when all it took was a five minute conversation. This was quite a learning experience.

3.3 Brian

My first task was to set up the NRAO computer. The computer did not have a java compiler so I downloaded one on the internet. A java compiler is required for the SRT software. In order to compile a program the instruction "set CLASSPATH =" must be typed in the directory with the file before the program can be compiled. I tried to add the directory with the java code to the CLASSPATH variable but this did not work. Once the computer was set up I installed Microsoft Office with PowerPoint. We used PowerPoint to make educational slideshows for the public. Our customer wanted a touchscreen for the user interface. I found a touchscreen supplier in Albuquerque called MassWorks. They sell a small color LCD touchscreen that connects to the computer via a USB port connection. The layout software that comes with the touchscreen can be integrated with any computer application. At this time I have set up the touchscreen to run the VLA

weather software, the VLA web pages, the educational slideshows, and the tracking software with the PowerPoint presentation.

I set up three main layouts because some objects are not visible at certain times of the year (figure 3.3.1). The layout on figure 3.3.1a has the Sun, Cygnus A, and Cassiopeia available for tracking. This layout will be used from November through May. The layout on figure 3.3.1b has only the Sun and Cassiopeia available. Cygnus A is not on this layout because it is only visible in the northern hemisphere from June through October. The layout on figure 3.3.1c will not have any objects available to track. This layout will be used if the SRT must be inactive due to weather conditions or technical difficulties. People will only have access to the slideshows, web links, and VLA weather. A technician will have to change layouts at the appropriate time.
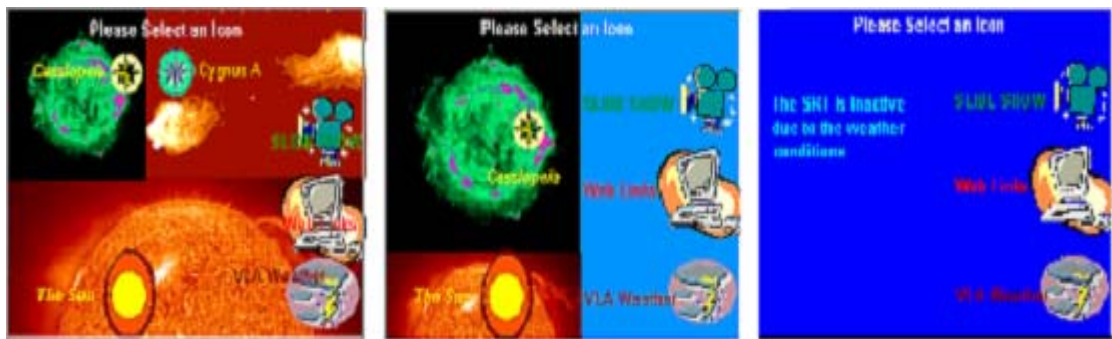

Figure 3.3.1a   Figure 3.3.1b   Figure 3.3.1c

Figure 3.3.1 The Main Layouts

There are three slideshow presentations. One slideshow will run when the Sun, Cygnus A, or Cassiopeia is selected on the touchscreen. The SRT takes about five minutes to track a celestial object. This slideshow is set up to keep people interested during this tracking down time. To run two programs at the same time two dos prompts must be open. The mouse pointer is first positioned on a DOS prompts to run the java program. Then mouse pointer is then positioned on the other DOS prompt to run the PowerPoint presentation. The mouse pointer is positioned using the touchscreen software. Once the PowerPoint presentation is finished the java software will run until a user selects the exit

button on figure 3.3.2. The exit button will exit the java program and load the main layout.

Figure 3.3.2 The Exit Layout

The other two slideshows are accessed when a user selects slide show on one of the main layouts. Both "How the SRT works" and "The Science of Radio Astronomy" buttons on figure 3.3.3 will run the PowerPoint presentation and load the layout on figure 3.3.4a. The back to main button will sent the user back to the main layout. The layout on figure 3.3.4a will allow the user to automatically go through the presentation or go to the next slide. The automatic button on figure 3.3.4a goes through the selected slideshow at a timed interval. The next slide button on figure 3.3.4a will change slides and load the layout on figure 3.3.4b. This layout will not have the automatic feature. The user will only have access to the next slide button. At any time when a slideshow is selected the user will have the ability to exit the slideshow. The exit buttons on figure 3.3.4a and figure 3.3.4b will exit the slideshow and send the user back to the layout on figure 3.3.3. The exit button must be selected to go back to the layout on figure 3.3.3 if next slide is selected. The automatic button will load the layout on figure 3.3.3 after the slideshow is completed.

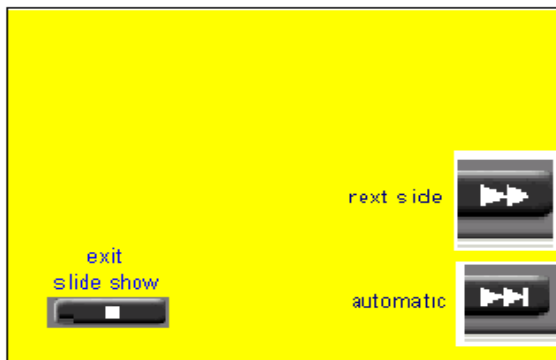**Figure 3.3.3 Slideshow Presentation Layout**

Figure 3.3.4a

Figure 3.3.4b

The VLA weather button will load a NRAO weather program to display on the monitor and the layout on figure 3.3.5. The weather program will tell people what the current weather conditions are at the VLA site. The back to main button will exit the weather program and send the user back to the main layout. The VLA weather program looks like the layout on the touchscreen. Data is received from the VLA control center via the network.
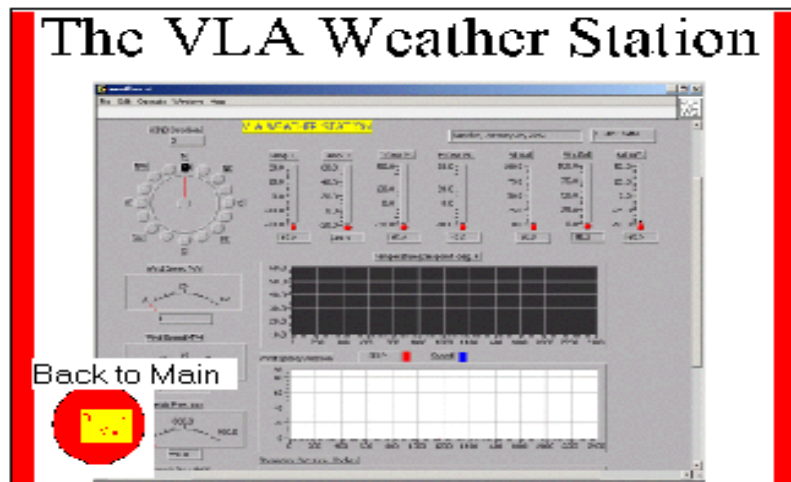
Figure 3.3.5 The VLA Weather Station Layout

When the web links icons are selected on Figure 3.3.3 the layout will change layouts to figure 3.3.6. The user will have access to three NRAO web pages. The FAQ web page has answers to common questions that people have about the VLA. The Careers at NRAO web page has the current job openings at the NRAO. The Radio Astronomy Images web page displays celestial images that the VLA produced. The back to main button will exit the opened web page and send the user back to the main layout. The page up and page down buttons will allow the user to scroll up and down the web pages.
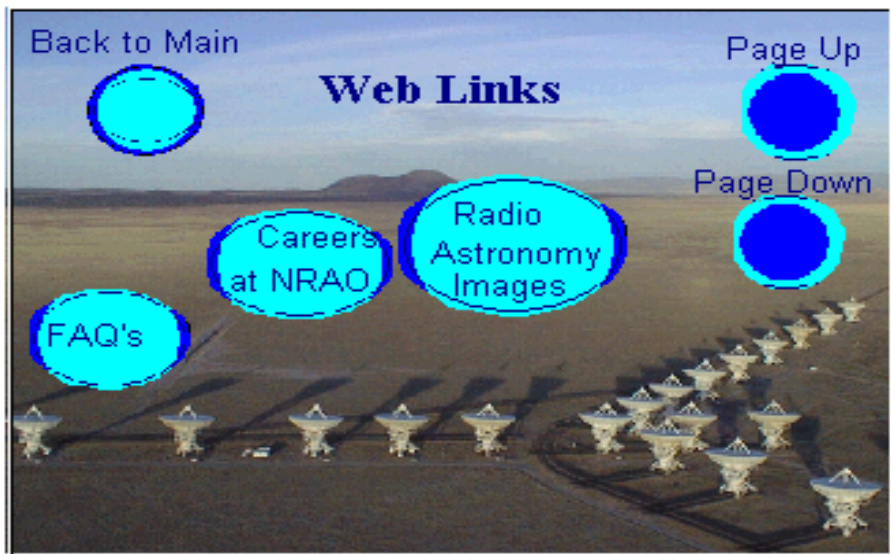

Figure 3.3.6 The VLA Web Links Layout

This feature was necessary because the web pages could not fit on one screen. The user will only have access to these three web pages. The web pages are accessed on the computer as a .htm extension file. This will increase the reliability because it does not depend on the network.

Each main layout had its own identical set of corresponding sub-layouts. This was necessary to link the layouts together because the sharing of layouts would create errors when trying to control the programs.

One problem with the touchscreen was when a button was pushed which had a command to change layouts. If the button on the second layout were in the same place as the button on the first layout, the button on the second layout would also be selected. This led to the problem of choosing an option that was unwanted. I tried to fix this problem by adding a delay after each layout. I thought a delay would give the touchscreen time to change before the selection becomes available, but this did not work so I was forced to have buttons in different locations when a layout changed. I think this is a flaw with the touchscreen software.

3.4 Group Efforts

In addition to weekly meetings in which we met with our clients and faculty advisor for updates, there were some tasks that we performed as a group.

The first task we accomplished as a group was finding a place to mount the SRT antenna for testing and development. We went through some brainstorming of ideas with our project advisor and supervisor on topics such as permissions for NRAO to have the antenna on Workman or another place on Tech property, liabilities, other design planning, other politics and even other possible sites like Etscorn Observatory and Gerald's house. We needed to find out if we would need administrative permission (Brown Hall), or if we would be infringing on any positions of Union workers from the

P-Plant or other government workers and whether we would need work-orders to complete our installation.

Because there are stanchions on the roof, which are designed to securely mount rooftop experiments such as weather sensors and antenna hardware, the idea of roof mounting the SRT on top of the Workman Building was appealing. Other reasons it was an appealing location was its accessibility and ability to be secured. Another factor that made Workman attractive was that our faculty advisor, Dr. Shanechi, graciously agreed to let us set up the development computer in his lab on the second floor. This saved us time, as we did not have to run the cables all the way down to the senior design lab on the first floor. We finally obtained permission to mount the SRT on the roof of Workman from the Physics Department chair, Dr. Minschwaner, after Clint Janes spoke with him. We met with the university architect, Dan Jones, to verify that the mounts on Workman were suitable for this project.

In early November, when the SRT kit finally arrived, our team got together to assemble and mount it on the roof of Workman. When we received the electronics and cable assemblies a short time later, we again got together to run them from the roof to the second floor lab. We all became familiarized with the antenna control program and the educational slide show demonstration. We also obtained a closed circuit television camera and got together to run the cable, again from the roof to the lab. The camera served two purposes. First, it provided us with visual feedback as to the dish's motion. Also, it provided a measure of safety by letting us know when people were on the roof or near the antenna.

In March, we took a trip to the VLA and saw the completed antenna mount and the installation of the conduit runs for grounding, control and signal wires along with a spare conduit that might be used for power. Communication with the carpenters about the design of the Monitor cabinet led to the conclusion that the cabinet would have to come from somewhere else. A decision was agreed upon as to the size of the fence that would enclose the SRT for safety considerations and to protect it from abuse. This information

was passed on to appropriate personnel. Then, tentative final delivery and installation dates were scheduled.

After development of the antenna control programs and educational tutorials, the team got together to deliver the kit to the VLA site in April. Together the team got the antenna and mounts taken apart, the cables pulled out, and everything loaded into the NRAO's panel-truck. We had a backup plan to store everything in the warehouse in case the installation went awry. At the site, we reassembled the kit and mounted it on the provided post in the enclosure built by VLA site personnel (Figure 3.4.1). Contact was made with the electricians to borrow a wire pulling-fish, ladder and some other tools. We managed to pull the signal wire into the installed conduit between the enclosure and the Visitor Center building and assemble the antenna without any problems. When we were trying to pull in the control cable, it got stuck because of too many 90 degree bends that were put into the conduit run. The VLA electricians were called to expedite cutting the conduit in the middle and to install an extra pulling elbow. The control cable was finally pulled through to the junction box at the base of the dish. The cables were pulled through the outer wall of the Visitor Center, but the junction box there was not completed. In addition there was a Coke vending machine in the way.

Figure 3.4.1 Reassembling the SRT at the VLA Site

Once the installation was complete, we connected the development computer and controller to verify that the telescope still worked. We were able to control the SRT with no difficulties, but since the kiosk wasn't ready we brought the computer back with us. Appropriate VLA building and maintenance personnel were asked to move the cabinets and displays that might be in the way of the SRT's kiosk. The Coke machine authorities would also have to be notified. We have since arranged for a couple more needed parts like a multi-strip outlet and grounding lugs. When the kiosk arrives, the space needed for it will be clear and we can schedule final installation and testing. We have also made arrangements to pass on documentation of the project to Phil Dooley, a VLA engineer.

4 Final State of Project

Figure 4.1 SRT at Its Final Location at the VLA

4.1 Final Testing

Initial development and testing was an on-going process. With the touch screen we tested operation and functionality every time we made a change or added a new feature. Proceeding in this manner we could ensure the system worked both in simulation runs and actual tracking of selected objects. With the final version of the software we have tested the system and it has worked every time. The system was tested on the site using the original software. This test worked and verified that the wiring was re-installed properly. From this we, have every reason to believe that it will work with our developed software.

We plan to meet with Phil Dooley an engineer at the VLA May 9th, after this paper is due. The purpose of this meeting will be to pass on responsibility for the project and give Mr. Dooley the knowledge he will need to set up the system when the last of the needed parts are assembled and put in place.

4.2 Functionality

Using a touchscreen a person can select to operate the SRT to track celestial objects. It will take approximately five minutes to initialize the system to start tracking. During this time an educational slide show will run explaining what the viewer is about to watch. There are also tutorials on The Science of Radio Astronomy and How the SRT Works. Additional features include NRAO Web pages and The VLA Weather Station, a LabVIEW program used by VLA astronomers.

5 Summary and Recommendations

This section describes effect of our work on this project. In addition, we have outlined some possibilities for further improvement of the SRT and some recommendations for maintaining it.

5.1 Summary of Current Work

Our work has enable NRAO to provide a sophisticated instrument that the general public can access and use to learn about radio astronomy. The SRT kit designed by MIT is suitable for astronomy students or scientists. We have adapted it to be suitable for people who do not necessarily have any technical knowledge.

Some other possibilities for applications of our work include using our simplified interface and program to benefit science hub schools. In addition, the idea of making CD's of the slide shows available to generate revenue has been raised.

5.2 Recommendations For Future Work

A nice addition to this project would be to have the java program stay open all the time to keep the SRT running and still have a choice of selecting other educational demonstrations. This will cut down on the time it takes to track an object. As it is, the SRT must find its motor limits every time the java program starts up. Furthermore, the java program must shut down to change celestial objects because the objects are selected through the command line. The program must be restarted every time the user wants to select a different object. Further work with the touch screen interface and the program's command structure would eliminate this requirement.

Automatic features in software could be used to stow the dish (pointed up at the zenith) when inactive or under severe weather conditions. If we had more time we would like to incorporate the VLA weather station program to flag on a high wind indicator and the

SRT program would cue make the antenna automatically stow and load the touchscreen layout which will inform the public that it is inoperable.

Another idea would be to open two programs at the same time with one dos prompt. Currently when a celestial object is selected two dos prompts are needed because two programs are used. One prompt will run the tracking software and the other will run the PowerPoint presentations. At the present time, mouse positioning is used to change dos prompts. This is not the best way to do this because over time the mouse can get out of position. A Visual C++ program could be created which will open both programs using one prompt. This will eliminate the need to position the mouse creating a cleaner running program. A copy of Visual C++ would need to be installed on the computer and we would need to learn how to use it to accomplish this task.

More radio sources could be made available for selection including terrestrial sources and geosynchronous satellites. This would be a simple addition to the program, requiring minimal changes to code.

An interesting Senior design project would be to upgrade the SRT controller. Possible improvements would be to add a better microcontroller and a DSP chip to perform signal processing that the SRT program is not capable of.

More information about the VLA could be made available in the SRT display like incorporating VLA observation schedules. The SRT project slideshow could also be made to run along with the educational slide shows.

Another possible addition is having a Web cam available to allow access from the web. Its website could be configured to control the SRT from a remote location.

Our project has inspired the NMT Physics Department to begin work on an array of multiple SRT antennas. This project had been planned previously, but they needed incentive to initiate production.

A printer could be made available for screen shots of the control display (easy to implement) to generate revenue for the VLA Visitor Center from it.

5.3 Recommendations For Maintaining the System

In providing for some minimal maintenance a technician should grease it at the provided fittings, check bolts for tightness, and verify alignment of vertical axis chassi. A technician should run the SRT program once upon startup to verify operation. A technician should Change layouts in November and June when objects to be selected are not visible (please see Touchscreen Operator's Manual in appendix).

Appendix:

Touchscreen Operators Manual

1. Left click on the start icon
2. Select programs/Massworks/ID-75 Layout Software to start the layout program
3. To open a layout , click on file and open>>Program Files/MassWorks ID-75/Layouts. In the Layouts folder there are three folders that the SRT uses.

    stow – Used when the SRT is inactive.

    cass,sun&cygnus – Used when all three sources are visible (Cass, Sun and Cygnus). Used from June through October.

    cass&sun – Used when only two sources are visible (Cass and Sun). Used from November through May.

Each of these folders has three main layouts.

    (stow) – The main layout is stow.lay. Open this by choosing file and open. Follow steps 8 and 9. Once the main layout has been set all other corresponding layouts will load automatically.

    (cass,sun&cygnus) – The main layout is cass2.lay. Open this by choosing file and open. Follow steps 8 and 9. Once the main layout has been set all other corresponding layouts will load automatically.

    (cass &sun) – The main layout is cass2noCygnus.lay. Open this by choosing file and open. Follow steps 8 and 9. Once the main layout has been set all other corresponding layouts will load automatically.

4. Once a layout is open a buttons is created by right mouse clicking on an empty space on the layout and selecting insert and choosing Macro. A "macro" can be a list of keyboard or mouse actions or events to perform when the button is pressed or released.   The event is received from the controller by the button in the layout. Each button can have many macros of actions to carry out.

5. A button is modified by right mouse clicking on it and selecting properties. All of the macros can be modified from this window.

6. For a more detailed method of creating or editing buttons select the help menu.

7. Text can be added to the layout by selecting insert and choosing Text. This will not create more than one line of text at a time.

8. A layout is sent to the device by left mouse clicking on the yellow lightning bolt icon on the toolbar.

9. The message "The layout has been sent to the device" will appear, click ok.

10. Slideshow timing can be modified. The time between slides can be changed by opening up the corresponding layouts that have an automatic button. There are three layouts for each slideshow with an automatic button that will need to be changed if any one is changed.

> Program Files/MassWorks ID-75/Layouts/stow/stowsrt(science).lay
>
> Program Files/MassWorks ID-75/Layouts/stow/stowsrt(works).lay
>
> Program Files/MassWorks ID-75/Layouts/cass&sun/stowsrt(science).lay
>
> Program Files/MassWorks ID-75/Layouts/cass&sun/stowsrt(works).lay
>
> Program Files/MassWorks ID-75/Layouts/cass,sun&cygnus/stowsrt(science).lay
>
> Program Files/MassWorks ID-75/Layouts/cass,sun&cygnus/stowsrt(works).lay

To do this count which slide needs to be modified. Right click on automatic button and select properties. The delay for each slideshow change is before the corresponding space bar command. Double click on the chosen delay to change the timing. (example: 22 seconds = 22000) Change this same line in each of the other two automatic button layouts for the slideshow.

11. Close the program so the window will not hamper the operation.

12. Do a test run by selecting the VLA weather button on the layout and then press the back to main button once the weather station is up.

For more information go to the website at http:/ /www.massworks.com. This website will contain help on using the touchscreen.

Compiling and Running a Java Program

1. Change directories to the one with the Java program that you want to compile.
2. Type "set CLASSPATH=" on the dos prompt.
3. Type javac filename.java.
4. If the program compiled with no errors filename.class will be created.
5. Run the program by typing filename.java.

Kit Specs

(Schematics located on CD)

Radiometer Characteristics

L.O. Frequency range	1370-1800 MHz
L.O. Tuning steps	40 kHz
L.O. Settle time	<5 ms
Rejection of LSB image	>20 dB
3 dB bandwidth	40 kHz
I.F. Center	40 kHz
6 dB I.F. range	10-70 kHz
Preamp frequency range	1400-1440 MHz
Typical system temperature	150K
Typical L.O. leakage out of preamp	-105dBm
Preamp input for dB compression from out of band signals	-24 dBm
Preamp input for intermodulation interference	-30 dBm
Square law detector max.	4000 K a 0 dB attenuation 40,000 K at 10 dB attenuation
Control	RS-232 2400 baud

Antenna Specifications

Manufacturer	Kaul-Tronics Inc.
Model Number	(S-7.5)
Diameter	90" (2.3m)
F/D Ratio	0.375
Focal Length	33.75" (85.7cm)
Gain @ 4.2 GHz	38.1 dBi
Gain @ 1.4 GHz	
Weight with mount	160 lbs
Beam Width	7.0 Degrees (L-band)

Gant Chart Explanations

In the following diagrams, as can be seen, the individual tasks of the overall project are placed on the left hand side while the time line (and deadlines) extends out to the right. The assignment of these tasks is distinguished by color-code (the key is in the bottom right hand corner) along with the coding for the tasks that everyone (black) will participate in. The longest tasks (paths) have been divided up according to experience and preference. The shorter paths have been assigned intuitively and thought of as challenges.

Some tasks have already been accomplished while some tasks, which were scheduled for later, were moved up and started on already. Still, there are some tasks that had to be "bumped" later because these time constraints have been relying on outside sources that have bogged down. Following the two full versions (Updated and Previous) of the time line Gant charts are listed short explanations of the individual tasks.

FIRST SEMESTER Tasks

Build and Mount SRT: Assemble the SRT kit and mount on Workman for testing

Run Cables: Pull cables through existing conduit to second floor lab

Setup Development PC: Install necessary software on PC provided by NRAO

Network Address: Connect development PC to Tech network

Java Compiler: Install Java Compiler on development PC

Simulate Dish Operation: Use SRT software to simulate tracking and
data collection

Develop Public Use System: Set up interface that the public can use to
control SRT and learn about radio astronomy.

Research/Order Parts: Find out about necessary components, particularly
a touchscreen

Touchscreen Implementation: Set up touchscreen for public use with
intuitive commands and attractive appearance

Interface Receiver Data: Process raw data coming from the receiver into a display (e.g. spectrum) that demonstrates VLA operation

Time and Location Update: Implement software or hardware to update computer clock for accurate tracking. Survey site to find exact dish location.

Implement Tracking Software: Look into using LabVIEW, TheSky, STS control system, or existing SRT software to track astronomical objects.

Calibration of SRT: Calibrate receiver to obtain accurate data

Electronic Noise: Method of calibration, more accurate than motorized vane

Motorized Vane: Alternative method of calibrating receiver

Watchdog Reset: Set up computer so that it and the display program restart without human intervention (in the event of power failure)

SECOND SEMESTER Tasks

Control Software Implementation: further development and use of existing SRT software for tracking astronomical objects and deadlines to reject other control software.

Research/order parts: Deadline for other controls software such as LabVIEW, TheSky, or STS control system.

Develop Public Use System-further development of touchscreen interface that the public can use to control SRT and learn about radio astronomy. As part of implementing the touchscreen for public use with intuitive commands and that has an attractive appearance

Research/order parts: this might be to get together with someone to design a counter to house the computer components that denies public access to the main computer except for the monitor and touchscreen

Data Processing: source incoming signals to appropriate displays

Spectrum Analysis: source incoming signals to appropriate displays

Educational Graphics: completion of educational displays

Other Displays: integration of other data files like weather or observation schedules and explanations of their relevance for public knowledge

Complete Installation: physically install the SRT at the VLA Visitors Center

Research/order parts: figure out what parts are needed for the installation

Planning/Engineering/Contacts: design the final installation layout and make
contacts with appropriate personnel to get the jobs completed

Reports/Papers/Presentation Material: ongoing production of paperwork

Final Documentation: write this SRT operation manual complete with diagrams

Compile Ongoing Diary: Putt together all email and correspondence as a
chronological history of the SRT project

Client E-mails

****

Date: Wed, 17 Oct 2001 14:25:37 -0600 (MDT)

From: Clint Janes <cjanes@aoc.nrao.edu>

To: brajala@nmt.edu, gbivens@nmt.edu, sfield@nmt.edu

Subject: project

My apologies for not making it to the meeting yesterday. Sam showed

me what has been going on and I'm really impressed, thanks!

Clint

PS: I'll try harder to make it next Tuesday.

Clint

****

Date: Wed, 17 Oct 2001 16:05:10 -0600 (MDT)

From: Clint Janes <cjanes@aoc.nrao.edu>

To: rharriso@zia.aoc.NRAO.EDU

Cc: brajala@nmt.edu, gbivens@nmt.edu, sfield@nmt.edu

Subject: Project

Hi Robyn:

     I am so pleased at the progress so far of the student project.

I suggest having the Visitor Center Committee meet at Tech next

time so that the students can demo and get additional suggestion.

Let me know if you agree and I can set up. Tuesday afternoon is

a good time for them.

Clint

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Date: Wed, 10 Apr 2002 17:18:29 -0600

From: Robyn Harrison <rharriso@cv3.cv.nrao.edu>

To: Clint Janes <cjanes@zia.aoc.NRAO.EDU>, Sam Field <sfield@nmt.edu>,

Gerald Bivens <gbivens@nmt.edu>, Brian <brajala@nmt.edu>,

Dr. Shanechi <shanechi@ee.nmt.edu>

Subject: SRT installation at site

Hi,

The fence went out to the site today. I think Charley plans to put it

up either tomorrow, Friday, or Monday at the latest so it should be

ready for you to move the dish itself out next week. We can't install

the internet cable until we have an actual cabinet to put the (I

forget what Fred told me goes between the end of the cable and the

computer) in, but anyway, it would be great if we could go ahead and

test it w/o the fiber link, though I know we need to update the clock,

etc. (Let me know and we can plan a time--we can store the computer in

the projector room if we need to). The cabinet builder gets back April

24. I expect we'll have the cabinet within a few days thereafter.

And Fred will probably connect the cable shortly thereafter, or the

same day--I'll be sure he gets it ordered before hand.

I'm sure I've forgotten something. If you think of it, let me know.

Robyn

Date: Tue, 30 Apr 2002 11:24:40 -0600

From: Robyn Harrison <rharriso@cv3.cv.nrao.edu>

To: Clint Janes <cjanes@zia.aoc.NRAO.EDU>, Sam Field <sfield@nmt.edu>,

Gerald Bivens <gbivens@nmt.edu>, Brian <brajala@nmt.edu>,

Dr. Shanechi <shanechi@ee.nmt.edu>

Subject: kiosk

Okay. This one was my screw up. I evidently miscommunicated what I
needed to the builder of the kiosk--at least as far as when we needed
it. I just talked to him and he thought I was still waiting to have
it approved. At any rate, he'll work on it this week and try to have
it done first of next week. What do you want to do?

Robyn

--

****

Robyn Harrison

Education and Public Outreach

National Radio Astronomy Observatory

Socorro, New Mexico 87801

505-835-7243

Date: Tue, 30 Apr 2002 13:16:28 -0600 (MDT)

From: Clint Janes <cjanes@aoc.nrao.edu>

To: brajala@nmt.edu, cjanes@zia.aoc.NRAO.EDU, gbivens@nmt.edu,
    rharriso@cv3.cv.nrao.edu, sfield@nmt.edu, shanechi@ee.nmt.edu

Subject: Re: kiosk

The students plan to meet with Phil middle of next week. We can
take it out if it is ready.

Clint