Communications challenge for the Gemini 8-m Telescopes

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ABSTRACT

We discuss the requirements and design of the communications system for the Gemini 8-meter Telescopes Project*. This system is unique not only in our integrated approach to data, voice and video, but it also must span the globe to reach the two telescope sites in Chile and Hawaii, and provide access to astronomers around the world. We discuss the various services planned for the communications system, the many locations which must be served, and the anticipated quality-of-service demands. The constraints which limit our options are also discussed. Finally we present our plans for meeting these challenges.

Keywords: communications, LAN, WAN, videoconferencing, telephony, ethernet, ATM

1. INTRODUCTION

The Gemini Project is an international partnership to build two 8-meter telescopes, one on Mauna Kea, Hawaii, and one on Cerro Pachon, Chile. The telescopes and auxiliary instrumentation will be international facilities open to the scientific communities of the member countries. The project includes not only the summit locations for the actual telescopes, but also base facilities in Hilo, Hawaii and La Serena, Chile; mid-level facilities at Hale Pohaku, Hawaii and Cerro Tololo, Chile; an International Project Office at a location to be determined; National Project Offices in each member country; and all the home institutions for the user community.

The communications system will be critical to the success of the Gemini Project. The following excerpt from the "Communication Vision for the Gemini 8-m Telescopes"[1] gives an idea of the extent to which we will depend upon communications.

> It is nightfall on Cerro Pachon and the system operator and staff astronomer are working through the beginning of the night's queued observations. While the system operator is watching the current satellite weather map to see how long the current conditions will last the service observer is deciding which mix of observations will make the best use of the site.
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> In the same room an engineer is trouble-shooting an off-line instrument via a video conference link to the Hilo base facility where the expert for this instrument is currently working. They compare notes, decide that it is the same problem fixed earlier this month on Mauna Kea, and transfer the patch file.
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> A few hours later as the system operator is running through the nightly calibrations of the telescope pointing and image quality the system operator for Mauna Kea starts up a video link. She is having problems with the M1 support system and wants to consult. While the Cerro Pachon telescope automatically runs through its calibration procedure the two system operators decide that it is the active actuator system which may be causing the problem. As the Cerro Pachon system operator has been through this procedure before he logs in to the Mauna Kea M1 support system using an engineering display and has a detailed look at the actuators' performance. Isolating it to a particular actuator which is misbehaving he advises the Mauna Kea system operator how to turn a particular support actuator off. The Mauna Kea system operator does so and then logs the problem in a distributed problem reporting system that will be used the next day by the day crew to repair or replace the actuator.

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*Managed by the Association of Universities for Research in Astronomy, Inc. (AURA) under cooperative agreement with the National Science Foundation

As the service observer is starting an infrared spectroscopic observation of a remote galaxy it becomes obvious that there is something peculiar about its emission lines. The service observer decides that this is worth calling the principal investigator in Cambridge, England about and then does so. After a brief teleconference discussing the different aspects of the spectrum the PI decides to log on to the system remotely and look at the spectrum himself.

The next observation is listed as classical remote observing and the observer has been waiting patiently in Tucson, Arizona to connect to the system and observe. She dials up the Gemini ISDN number and establishes a TCP/IP connection to the site, giving her control of the science operations. As she works the telescope updates a video image of the guide field as well as allowing her to interact via a full screen X window display, identical to that available on site. At the same time a video link allows her to interact with both the system operator and the service observer.

The ultimate goal for the communications system is to not be noticed. It ought to work so well that it is taken for granted, allowing users and support staff to go about their tasks. Achieving this will require extensive planning and a lot of hard work.

2. COMMUNICATION CHALLENGES

There are many challenges facing us as we finalize the design of the communications system and begin to implement it. Perhaps the most familiar challenge is cost. As with virtually any publicly-funded project, Gemini must operate with a limited budget. Money must be spent wisely and choices accounted for. Confounding this is the rapid progress in electronics and communications services. For almost every aspect of the communications work package, one could expect a significant price reduction in two years. New technologies are being developed and deployed at a dizzying pace. All of this makes the design of the communications system a delicate balance between what we can afford, what we need now, and what we expect to happen in the future.

Another challenge is geography. Both telescopes are in remote locations with inhospitable climates. Access to the sites is a major obstacle. Both Hawaii and Chile have limited access to services and equipment which is taken for granted in the mainland USA. The distance between the base and summit facilities as well as the altitude of the summit facilities (14,000 feet at Mauna Kea, 9,000 feet at Cerro Pachon) makes work at the summit difficult. And of course the distance between Hawaii and Chile provides a great challenge.

The local infrastructure (or lack thereof) poses another challenge. Cerro Pachon is a remote peak in the Chilean Andes. All access to and construction on the site has been initiated for the Gemini Project. In this case, the challenge also provides us the opportunity to bypass generations of old technology and install modern, proven equipment. In Hawaii, the telecommunications infrastructure lags far behind the mainland. Progress is being made, albeit sometimes at a frustrating pace.

Finally, the rapid pace of change poses an enormous challenge. Asynchronous Transfer Mode (ATM) networks are evolving and standards are being proposed, adopted, and superseded. Gigabit Ethernet is nearing standardization, and products are beginning to appear. Once proprietary videoconferencing systems are moving towards standardization and even operation over TCP/IP networks. Telephone switches are being introduced which replace the traditional desktop handset with a personal computer. Peering into the crystal ball of the future of technology is a daunting task.

3. USER REQUIREMENTS

An extensive list of user requirements has been developed.[2] This includes a number of communications areas:

- Data networking
- Telephone systems
- Videoconferencing
- Public address systems
- Video monitoring systems
- Mobile communications systems

Although this list is not all-inclusive, it does cover the major subsystems. Some of the requirements for these subsystems are discussed in the following sections.

3.1. Data networking

Data networking is a broad category, including both the local area networks (LANs) and the wide area networks (WANs). The data network is the single most important component of the communications system – if the computers can not access the network, the telescope can not operate.

There are some common characteristics for all our networks. All networks are required to carry TCP/IP traffic; there is no requirement to support other protocols such as IPX, DECNET or AppleTalk. All LANs are required to operate at a minimum of 10 megabits per second (Mbps). All components of the system should be specified such that inevitable upgrades are relatively simple.

3.1.1. Summit network

The network configurations for Mauna Kea and Cerro Pachon will be as similar as possible; currently they have identical designs. The summit network consists of four separate LANs: the Control LAN, the Data LAN, the User LAN and the Technician LAN.

The Control LAN is used for transmitting command, control and status traffic amongst the real-time systems which operate the observatory. These are mostly VME computers running EPICS.[3] Due to hardware constraints, this LAN will initially operate at 10 Mbps. Traffic volume on this LAN is expected to be moderate, but latency should be kept at a minimum.

The Data LAN is used for bulk data transport. The data sources on the Data LAN include the detector controllers, the wave-front sensors and the adaptive optics sensors. The data sinks are the Data Handling System workstations. There will be two typical traffic patterns: sudden large data sets between long periods of idle time (exposure and readout of optical detectors), and sustained transmission of small data sets (wave-front or adaptive optics sensor readouts, rapid readout of infrared detectors). Furthermore, the Data LAN should accommodate two simultaneous data sources and one data sink. This LAN will initially operate at 100 Mbps. For performance, this LAN should be isolated from all other LANs.

The User LAN is for scientific and engineering operations. This includes the workstations for observers, the workstations for the system support associates (aka telescope operators), and the workstations for the engineering staff to support the observatory operations. The response time of these workstations will greatly influence the perceived performance of the telescope. This LAN will initially operate at a minimum of 100 Mbps. However, the goal is to operate this LAN at 1000 Mbps.

The Technician LAN is for personal computers, printers and workstations not directly involved in the operation of the telescope. This will act as a “catch-all” LAN for the inevitable proliferation of computers at the summit. The main activities on this LAN will include sending and receiving email, access to documentation, browsing the web, and peripheral devices such as printers and plotters. This LAN will use the same technology as the Staff LAN at the base facilities, operating at 100 Mbps but accommodating 10 Mbps devices.

3.1.2. Base facility network

The network configurations for Hilo and La Serena will be as similar as possible; currently they have identical designs. The base facility network consists of five separate LANs: the Control LAN, the Data LAN, the Operations LAN, the Staff LAN and the Astronomer LAN.

The base facility Control LAN and Data LAN will be a smaller version of their respective summit LANs. They will provide the ability to operate instruments in the base facility shops. Additionally, access to these LANs may be extended so that support staff can service instruments from their offices.

The Operations LAN will only span the Operations Room. This will be a large room at each Gemini base facility which is fully equipped for interacting with the systems at the summit as well as the twin telescope in the other hemisphere. It should be capable of supporting all the activity which occurs on the summit User LAN. Additionally, the Operations LAN will receive and archive all data generated at the summit. The Operations LAN will use the same technology as the summit User LAN, operating at a minimum of 100 Mbps with a goal of 1000 Mbps.

The Staff LAN is the general purpose LAN for the base facility. Most workstations, personal computers and peripherals will be attached to this LAN. It will operate at 100 Mbps, but will need to accommodate 10 Mbps devices.

The Astronomer LAN will accommodate the data storage, access and processing needs of the scientific staff. The sheer volume of data generated will present new challenges in the efficient processing of this information. For example, a single image may be 512 megabytes. Data reduction and analysis for such an image, together with various flat field images and calibration images, will generate a large amount of data traffic. This LAN will operate at a minimum of 100 Mbps.

3.1.3. Mid-level facility network

The mid-level facility networks are not integral to the operation of the observatory. These LANs need only support such basic needs as email, access to status information, and occasionally viewing data. Neither data processing nor telescope operation will take place at the mid-level facilities. Since we will be "guests" in the respective mid-level facilities, we will have less control over the network topology. The mid-level LAN will operate at a minimum of 10 Mbps, but we hope to use the same technology as the summit Technician LAN and the base facility Staff LAN.

3.1.4. Wide area network

There are three different WANs which need to be developed for Gemini: the Mauna Kea to Hilo WAN, the Cerro Pachon to La Serena WAN and the Hawaii to Chile WAN. The connections to Hale Pohaku and to Cerro Tololo need also be considered, but they are expected to fall out of the other work.

In Hawaii, GTE Hawaiian Telephone Company has put a fiber-optic OC-12 (622 Mbps) line in from the summit of Mauna Kea down to both Hilo and Waimea. They will be leasing bandwidth on this configured as individual DS-3 (45 Mbps) segments. Initially the Gemini Project will lease one DS-3 segment. This will support not only our Hilo to Mauna Kea data network, but also our videoconferencing and telephone system. Internet access may have to traverse this segment, and we may have to sublet some of the bandwidth to other observatories. Clearly this WAN must be designed to accommodate a variety of uses as well as (imminent) future expansion.

In Chile, there currently is no network access to Cerro Pachon. This is a new site and Gemini will be the first facility located there. Given the remote location and the lack of customers (compared to more than ten telescopes on Mauna Kea), it is unlikely that any telecommunications company will be willing to undertake the expense of running fiber network lines. We must therefore explore alternatives for network access. "First light" is scheduled for Gemini North in December 1998 and for Gemini South in December 2000. This gives us time to evaluate the WAN bandwidth required for the Gemini North link and apply these lessons to Gemini South. Two possible options are leasing old equipment from the Chilean telecommunications industry as it transitions from a backbone of microwave links along the Andes to a fiber backbone along the Pacific coast. This will give us an E-3 link (35 Mbps), which will likely be shared with other facilities in the area. Another option is to install millimeter-wave equipment giving us an STM-1 link (155 Mbps).

One of the most difficult aspects of the communications system is the Hawaii to Chile WAN. Given the distributed support model envisioned for the Gemini staff, reliable high-bandwidth communications between Gemini North and

Gemini South will be critical to the Project's success. Unfortunately, the cost of a leased line from Hawaii to Chile may make this a "hard sell". It is also the one area of the communications system over which we have the least control. We are not in a position to put up our own satellite or run our own trans-Pacific fiber. Thus we are dependent on commercial initiatives not only for service, but also for the cost-viability of the service. We will be exploring many options over the next two years. Possible options include an E-1 (2 Mbps) leased circuit, frame relay at multiples of 64 Kbps, and simple dial-up lines for voice traffic.

3.1.5. Connections to the Internet

Not only must the networks interconnect the various devices within the Gemini Observatory, they must also connect Gemini to the Internet. The topology of the Internet connections are largely out of our control. In Hawaii, the Internet connection via the University of Hawaii goes through Hale Pohaku. All Internet traffic to Hilo must therefore travel from Hale Pohaku through Mauna Kea and down to Hilo. This has obvious bandwidth and security implications.

In Chile, the current Internet connection for the Cerro Tololo Inter-American Observatory (CTIO) is via a 64 Kbps satellite link on Cerro Tololo to NASA. This link is already at full capacity and has too little bandwidth to accommodate the needs of Gemini. An alternative must be found. Fortunately, the network infrastructure in South America is progressing rapidly. Reliable, high-bandwidth commercial connections to the Internet should be available in the next few years.

3.1.6. Security

Network security is of paramount importance for the Gemini Project. Hundreds of tons of metal and glass will be under computer control. The health, safety and integrity of human lives, equipment and data must be ensured. The real-time systems chosen to operate the telescope have essentially no access controls or security mechanisms. Therefore all security must be enforced by the network.

There are many factors which complicate this. The scientific staff will come from academic institutions where security mechanisms are largely viewed as a hindrance to their pursuit of knowledge. Access to the Internet opens up a Pandora's box of security concerns, and yet Internet access is vital for development and maintenance of the observatory, public relations, and scientific pursuits.

Security will be addressed by extensive use if firewalls at all access points to the Gemini network as well as access and filtering rules on all routers. This will be augmented by an aggressive program of security auditing for all the workstations and personal computers in the Project.

Security must be treated as a first-class concern through all phases of design, implementation and operation of the communications system and not merely an after-thought.

3.2. Telephone systems

The telephone system is also part of the communications system work package. The requirements of the telephone system include all the usual features people now take for granted – voice mail, call forwarding, direct dial, etc. The unique feature for the Gemini telephone system is the desire to tie all the sites together into a single, unified system. For example, a worker on Cerro Pachon should be able to pick up the phone and dial a three digit extension and be connected directly to the staff on Mauna Kea. This level of integration is relatively easy within Hawaii and within Chile, but tying the entire observatory together is a greater challenge. In addition, provision must be made so that if at all possible, each part of the telephone system is still operational no matter what happens to the wide area connections.

3.3. Videoconferencing

Videoconferencing will play an integral role in the construction, commissioning and operation of both telescopes. Work for the Gemini Project is currently spread across the world, including England, Scotland, Canada, France, Belgium and throughout the United States. Videoconferencing has been used to coordinate activities; however, as it all comes together maintaining communication between the sites involved will be essential.

Once the telescopes are operational, videoconferencing becomes even more important. The staffing model foresees a single engineering team with technical responsibility for instruments and systems at both sites. Videoconferencing will be one of the fundamental tools used to keep the observatory running smoothly.

3.4. Public address systems

As with other telescopes, we plan to have a public address system in place at each summit. However, this will be integrated with the telephone system. A receptionist or other staff member at the base facility will be able to page individuals at either summit.

3.5. Video monitoring systems

A video monitoring system will be in place at each summit. The primary purpose of this system is to ensure the safety of people and equipment while operating the telescopes. These cameras will operate over dedicated cabling which will converge in the machine room. There the signals will be digitized and the various camera views will be made available to the workstations on the network. Dedicated video monitors may be used as well.

3.6. Mobile communications systems

The final major subsystem of the communications system is mobile communications. This extends from walkie-talkies within the observatory to pagers to cellular phones to vehicle-mounted radio phones. Again, the primary emphasis is on safety and communications in emergencies. Undoubtedly these systems will prove useful in the day to day operations of the telescope as well.

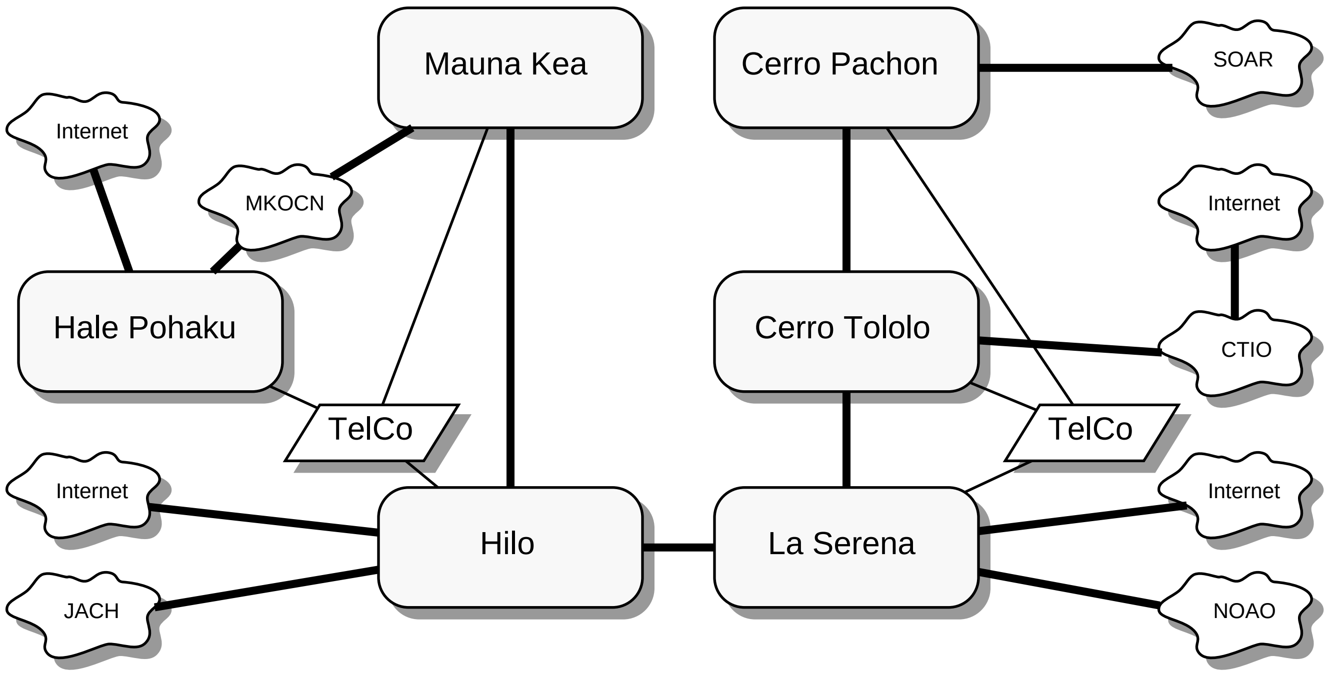

Figure 1. Wide area network

4. PROPOSED SOLUTION

The Gemini Project's communication systems is still in the design phase. It is anticipated that the summit communications systems will need to be installed and operational before the end of 1997. Thus work continues at a frenetic pace. Here we present the current vision for the communications systems design. Since this is very much a work in progress, and because of concerns for fair bidding practices, this will necessarily be vague in areas.

4.1. Wide area network

The WAN links are shown in figure 1. This figure shows just how many different outside connections we will have to support in addition to those necessary for our internal communication. The telephone company (TelCo) connections provide voice and dial-up ISDN service. Even though our main telephone system will integrate all sites, we still require individual telephone lines to each site for emergency backup.

The Joint Astronomy Centre, Hilo (JACH) operates two telescopes on Mauna Kea. It is likely that we will sublet some of our bandwidth to them.

The Mauna Kea Observatories Communication Network (MKOCN) is currently an FDDI token ring which connects all the observatories on Mauna Kea to each other and to Hale Pohaku. Plans are underway to replace this FDDI token ring with an ATM network.

The National Optical Astronomy Observatories (NOAO) operates a number of telescopes at CTIO. It is likely that we will sublet some of our bandwidth to them.

The Southern Observatory for Astronomical Research (SOAR) is a consortium with plans to build a 4-m telescope on Cerro Pachon. It is likely that we will sublet some of our bandwidth to them.

There are a number of possible connection points to the Internet. Not all of them will be implemented. Each will have to be evaluated in terms of cost, bandwidth and security.

The links leading out of the Gemini Observatory sites will only be required to carry TCP/IP traffic. All links between Gemini sites must carry TCP/IP data as well as telephone and videoconferencing traffic. Furthermore, these links must have a mechanism to meter the data flow and provide guaranteed quality of service. These links will use ATM.

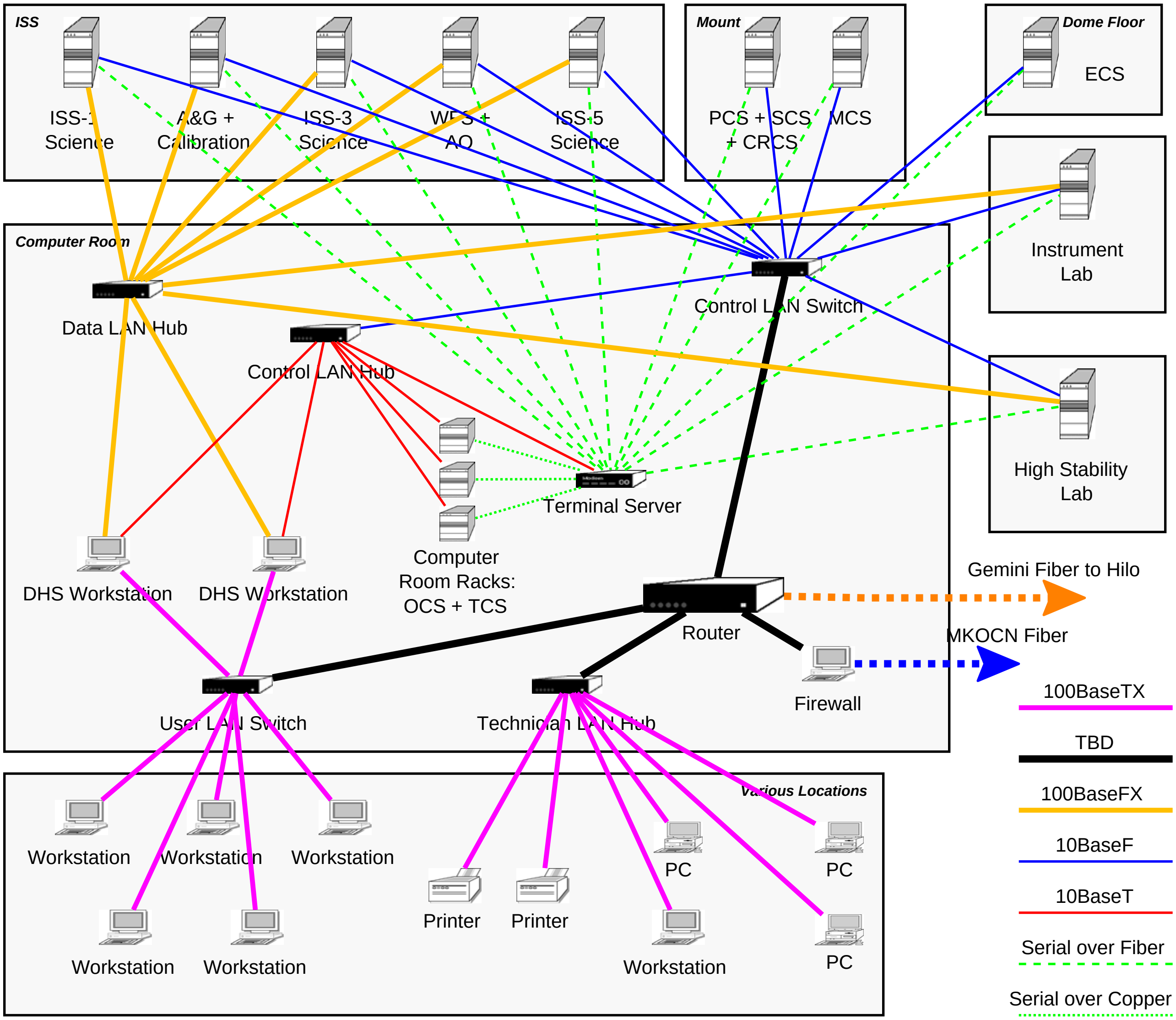

Figure 2. Summit facility

4.2. Summit facility

The various LANs within the summit are shown in figure 2. This figure does not indicate the telephone switch, the videoconferencing equipment, the video monitoring equipment, the public address or intercom systems. It gives some idea of the complexity and distributed nature of the summit LANs. The figure depicts the Mauna Kea layout, but the Cerro Pachon networks will be nearly identical.

This figure introduces a number of new terms and acronyms, many of which are not relevant to this discussion of the communications system. The Instrument Support Structure (ISS) is a large steel cube, approximately 1.5 meters along each edge. The instruments are bolted to five faces of this cube, while the sixth face is bolted to the telescope's cassegrain rotator.

The Mount is the large rotating concrete section of the dome floor on which the telescope is mounted. This provides the azimuth movement for our azimuth/altitude telescopes. The dome floor is the non-rotating area within the dome.

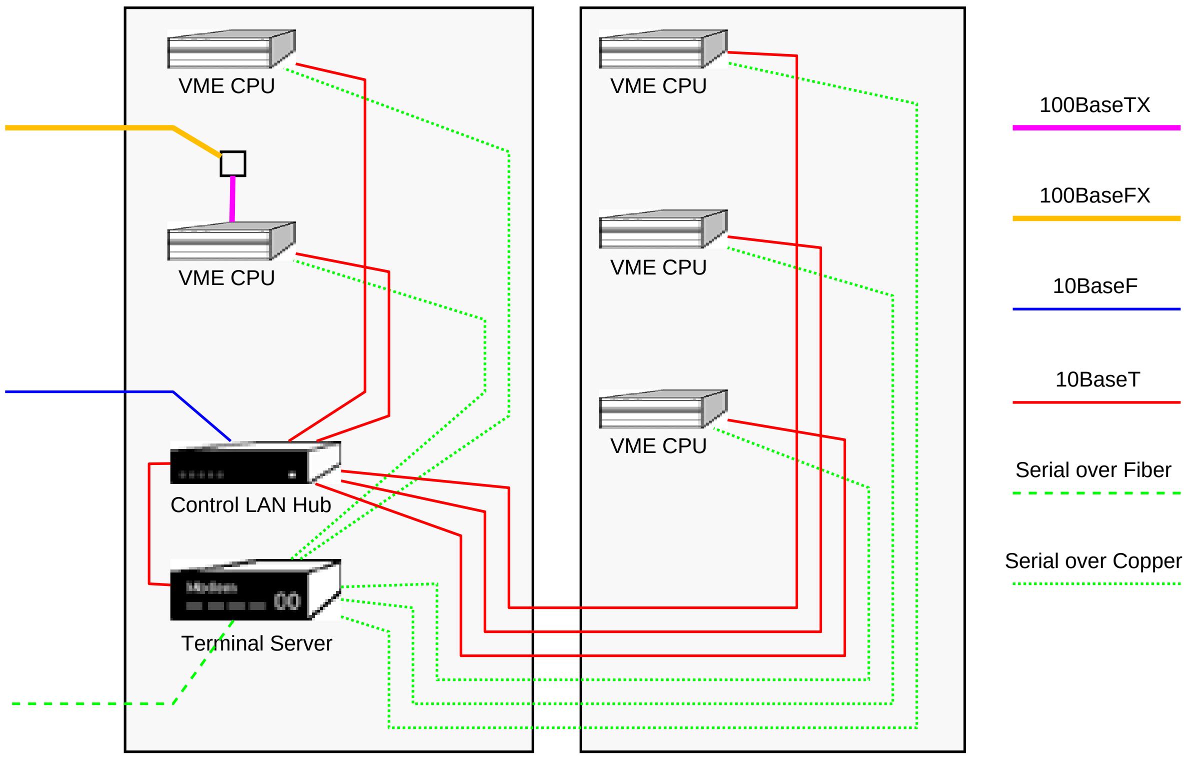

Figure 3. Instrument thermal enclosures

The high stability lab is located in the central pier two stories below the telescope. This will be used for high-resolution spectroscopic instruments.

The instrument lab is used for preparation and repair of instruments. The computer room holds many of the servers and network equipment. Both of these locations are in a building adjacent to the dome structure.

Finally, there will be workstations scattered throughout both buildings.

In figure 2 there are ten subsystems indicated at various locations throughout the dome. Each of these support one or more science instrument or major telescope subsystem. Every instrument may have one or two thermal enclosures. Within these thermal enclosures there is yet more networking. Figure 3 shows some of the possible connections for each instrument.

Each instrument may have a number of different processors to support the various monitoring, control and data acquisition tasks required. Each processor will have a network connection and a serial connection to be used as the processor's console. Every thermal enclosure will have a 10BaseT hub to connect the processors to the Control LAN. This hub will connect back to the computer room via 10BaseF.

The serial lines within the thermal enclosures will all be brought in to a single terminal server which can be accessed across the network. The terminal server will be connected to the 10BaseT hub. There will also be one serial line from each terminal server, run via fiber, which is brought back to the computer room. This link may be used for diagnostic or maintenance purposes.

For every instrument, there may be a maximum of one connection to the Data LAN. This connection will run from the computer room via fiber to the instrument. Inside the thermal enclosure, the 100BaseFX line will be attached to a media adapter which will then provide 100BaseTX to be used with the processor's Data LAN interface. This must be done to accommodate the limited selection of physical layer interfaces available on VME systems.

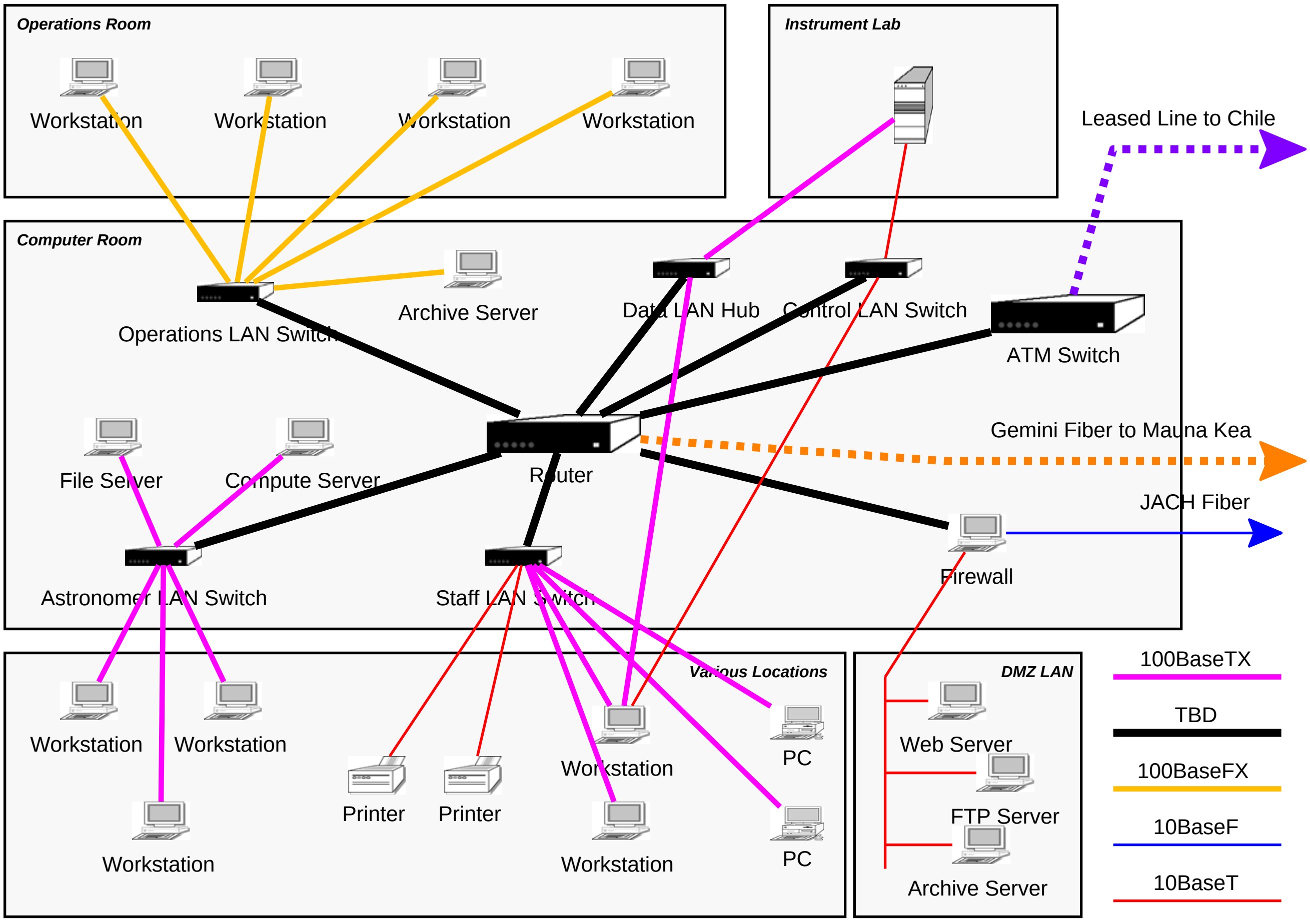

Figure 4. Base facility

4.3. Base facility

The various LANs within the base facility are shown in figure 4. This figure does not indicate the telephone switch or the videoconferencing equipment. The figure depicts the Hilo layout, but the La Serena networks will be nearly identical.

The computer room houses most of the network equipment as well as a number of servers. This will also be the termination point for the outside links, such as the TelCo connections, the leased line to Chile, the DS-3 fiber link to Mauna Kea and the tie to the JACH.

The operations room will have a number of workstations available, and will also hold the videoconferencing equipment.

A multitude of workstations and personal computers will be distributed throughout the base facility. Some of these workstations will also have connections to the Data LAN and the Control LAN in the instrument lab.

All the publicly accessible servers will be on the outside of our firewall in a "de-militarized zone" (DMZ). This security precaution is to ensure that access to the public servers is easy, but break-ins on these computers will not compromise the integrity of any other computer.

4.4. External connections

In addition to the WAN connections already discussed (Hilo to Mauna Kea, La Serena to Cerro Pachon, and Hawaii to Chile) and the TelCo connections to each site for telephone service, there will be a few more external connections. Each base facility will have a number of ISDN lines. These ISDN lines will be used for videoconferencing to outside sites. Additionally, it is a goal to provide every staff member with ISDN network access to the base facility. This will be used for data networking and videoconferencing to support operations at the various Gemini sites. We may also allow off-site users of the telescopes to access the ISDN dial-in lines if better throughput is required than is available via the Internet.

5. CONCLUSION

The communications system is vital to the success of the Gemini 8-m Telescopes Project. It is at the core of much of the observatory's work. The design and implementation are progressing rapidly. The goals for the system are to meet all the stated requirements, to provide an easy path for future upgrades, and to operate in such a way as to not be noticed.

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