# Network Infrastructure Improvements at Gemini

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## ABSTRACT

Gemini* has recently been awarded two NSF grants to be used for enhancing the network connectivity in Hawaii and in Chile. We discuss our plans for these grants. Of special note is the collaborative nature of these grants, and how multiple organizations can leverage individual contributions with results greater than can be achieved separately.

**Keywords:** communications, networking, NSF

## 1. INTRODUCTION

The Gemini Project is an international partnership to build and operate 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; Gemini offices in Tucson, Arizona; National Gemini Project Offices in each member country; and all the home institutions for the user community.

Voice, video and data communications are critical to the success of the project. A single staff with a limited number of experts is tasked with building and operating both telescopes. These sites are separated in both time and space. It takes a full two days to travel the thousands of miles between Gemini North and Gemini South. It takes two hours to travel from either base facility to the respective telescope. Communications systems enable quick responses to problems.

Gemini is an international partnership. In addition to communication within Gemini, we must support communication to partner countries. As Gemini moves into scientific operation during 2000, this will become increasingly important.

Recognizing this, the NSF has awarded Gemini two grants for use in improving the network infrastructures in Hawaii and in Chile.

## 2. THE PARTNERSHIP

The Gemini partnership includes the United States, the United Kingdom, Canada, Chile, Argentina, Brazil and Australia. Each country maintains an active National Gemini Project Office (NGPO). These sites regularly collaborate with the International Gemini Project Office (IGPO) in Hilo, Hawaii on scientific, technical and administrative matters.

The Gemini telescopes have been built by work packages subcontracted to sites throughout the world. This includes the enclosures, telescope structures, mirrors, control systems and instruments. This has necessitated communication with contractors in all stages of work package development - design, fabrication, assembly, testing, delivery, installation and support.

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*The Gemini 8-m Telescopes Project and Observatory is managed by the Association of Universities for Research in Astronomy (AURA), for the National Science Foundation (NSF) and the Gemini Board, under an international partnership agreement.

Gemini's customer is the scientific community from all the member countries. Gemini has set forth an ambitious model for queue and remote observing in addition to classical observing. Critical to these modes will be the communication systems.

## 3. THE SCIENCE

One of the many innovative aspects of Gemini is the ambitious plan to support new modes of observing. Scientific use of Gemini will fall into three categories: classical observing, remote observing and queue observing.

### 3.1. Classical Observing

Classical observing time is characterized by having the Principal Investigator (PI) or their designee present at the telescope while their science program is being executed on the telescope. We refer to this as classical observing since it is the way most of the visible and infrared telescopes to date have been operated.

This process starts with the PI using the Gemini Phase One Tool (POT) to design a science program and then submit it to the time allocation committees for peer review. Use of the POT does not depend on any network connections. However, an online helpdesk will be available for the community to answer questions which may arise in preparing a science program. Submission of the science program for review will be done electronically.

Once a science program has been accepted, the PI further refines the science program using the Gemini Observing Tool (OT). With this, all aspects of an observational sequence will be defined before the PI ever arrives at the telescope site. The motivation for this is to make more efficient use of telescope time. The OT requires a network connection to Gemini to interact with the observing database.

At the telescope, the PI will be present as the science program is executed by the system support associate (SSA, a.k.a. telescope operator). The PI can interact with the system to make changes in response to current conditions or unexpected results.

Scheduling of the telescope for classical observing will typically be in units of a whole night.

### 3.2. Remote Observing

Remote observing is similar to classical observing except that the PI interacts with the Gemini staff from a remote site. This remote site will either be the PI's home institution or a remote observing station set up at the country's NGPO. There are significant requirements for voice, video and data communications to implement remote observing.

Scheduling of the telescope for remote observing can be in units of half nights or less. Thus we may need to set up communications to a number of sites throughout the world each night.

### 3.3. Queue Observing

Queue observing is identical to classical observing and remote observing in the stages where the science program is defined. However, once the science program is accepted and fully defined it is entered into a Gemini database. During the course of the night, Gemini Observatory Control System (OCS) software will select from the database the most appropriate observation based on numerous criteria. The observation will be carried out by Gemini staff and the results will be communicated back to the PI. It is a goal to keep PIs informed in real time about what is happening on the telescope. Thus the PI can begin to examine the results soon after the observation has completed and will have the opportunity to feed back their input. This mode of observing will benefit from the ability to transmit large amounts of data efficiently.

Scheduling of the telescope for queue observing can be in units of single observations. We will need good network connections to the astronomy community in all the partner countries in order to disseminiate the data as needed.

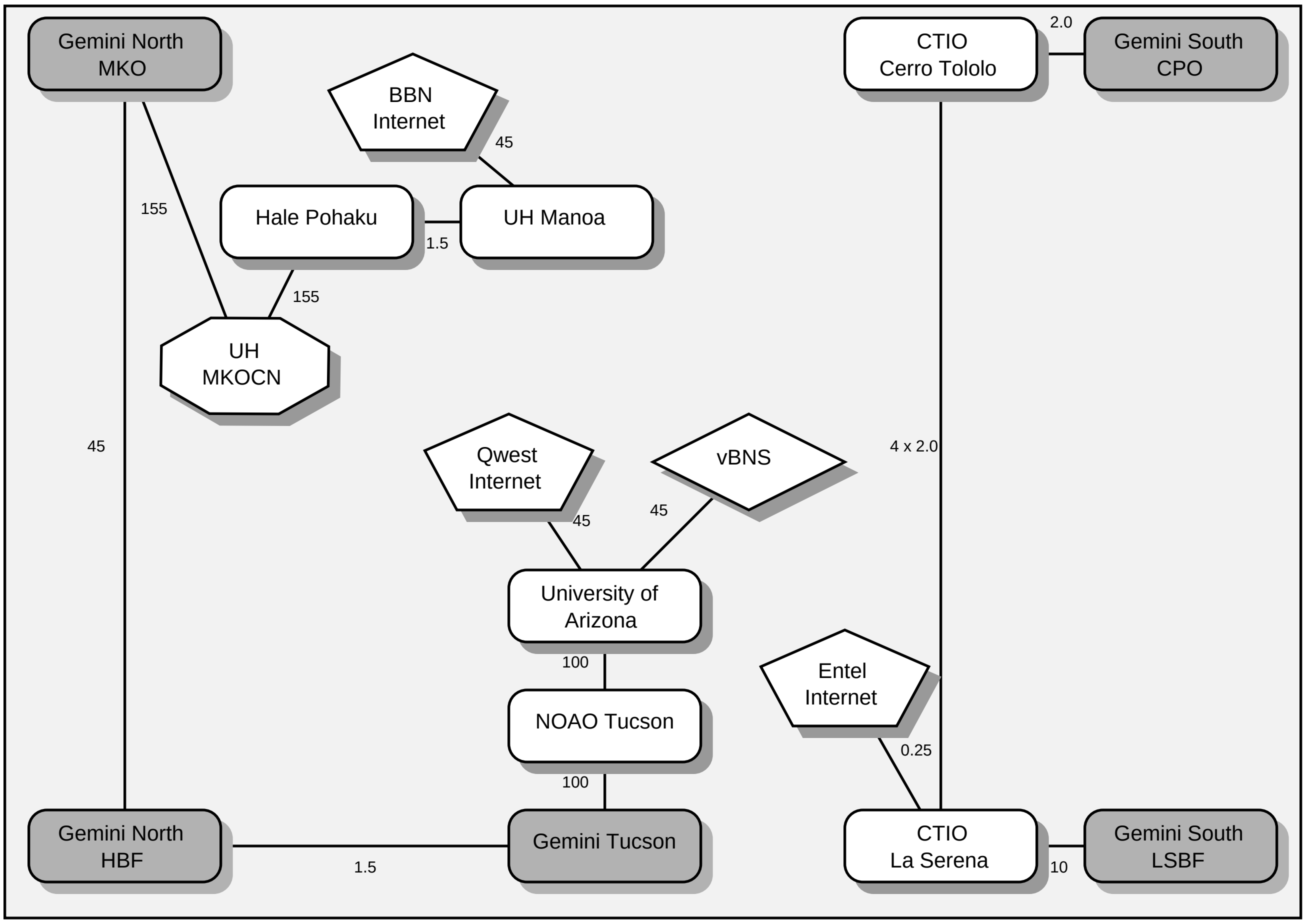


**Figure 1.** Network configuration before Gemini NSF grants.

## 4. NSF GRANTS

Figure 1 shows the network situation before the Gemini NSF grants. Diamonds represent next generation Internet networks. Pentagons represent commercial Internet networks. Octagons represent locally run inter-networks. For each link, the bandwidth in Mbps is shown.

For Gemini North the bottleneck is the 1.5 Mbps frame relay connection from the mid-level facilities at Hale Pohaku to the University of Hawaii-Manoa on Oahu. This connection is shared by eleven observatories on Mauna Kea. As all observatories continue to make more use of the Internet, this link is inadequate.

For Gemini South there are many bottlenecks. Gemini is the first facility on Cerro Pachon so there are many areas where we can not make use of existing infrastructure. As much as possible, we have tried to leverage the infrastructure developed by the Cerro Tololo Interamerican Observatory (CTIO). We bought a BreezeLink wireless ethernet bridge from BreezeCom to span the gap between Cerro Tololo and Cerro Pachon. CTIO has four leased E1 lines from La Serena to Cerro Tololo. Gemini has sublet two of these - one for TCP/IP traffic and one shared between voice and video. The existing 0.256 Mbps Internet connection is not adequate for Gemini's needs even at this early stage of construction. As we quickly make progress, this Internet connection will become even more of a bottleneck.

Gemini's offices in Tucson are well connected. Through the National Optical Astronomy Observatories (NOAO) and the University of Arizona, we have access to both the commercial and next generation Internet at high speed. Gemini has leased a low speed connection between our Hilo and Tucson offices. This ensures communication between our offices even when the University of Hawaii network is down. We do not pass Internet traffic over this link.

### 4.1. Hawaii Grant

The University of Hawaii (UH) recently received a US$350,000 grant to implement a high-speed connection from Oahu to the next generation Internet on the mainland and a high-speed connection from Oahu to the Island of Hawaii. UH, with the help of the NSF, was able to "piggyback" their traffic on an existing Department of Defense (DoD) connection to the mainland. This made the entire program affordable. With the remaining money, UH arranged to increase the bandwidth to the Island of Hawaii from 1.544 Mbps to 6 Mbps. This grant program is for a two year period. Contingent on receiving the grant, the institution must make a commitment to continued access to the next generation Internet.

Gemini was encouraged to pursue a similar US$350,000 grant to fund two years of a high-speed connection to the next generation Internet. We soon learned that UH had received their as-yet unannounced grant, and that working with UH would increase our buying power and increase our chances of receiving the grant.

The initial suggestion to submit a grant was received after the formal deadline for submissions had passed. Thus there was great time pressure to generate a complete proposal and submit it for peer review at the NSF. The chaos was only increased in the final days before the deadline when an alternative source of grant funds at the NSF appeared. This would be a US$600,000 grant, but the deadline for submission to the new program would be in two days rather than five days. With a flurry of activity, the proposal was finished and sent to Washington D.C.

News that US$600,000 had been awarded by the NSF to Gemini was received on 29 March, 1999.

After receiving the grant, the next difficult issue was exactly how to spend the money. The most important consideration for Gemini was to increase the bandwidth between Hilo and the next generation Internet. The most effective way to do this would be to join forces with UH. UH had already committed to funding a 6 Mbps link between Oahu and Hawaii (approximately US$93,000). Gemini had funds for about 14 Mbps between Hawaii and a neighbor island (approximately US$182,000). By pooling these funds, together we could lease a 45 Mbps link between Hawaii and Oahu. This is the single largest success of the grant.

Table 1 shows approximately how the grant money has been spent.

**Table 1.** Funds allocation from the US$600,000 grant awarded by the NSF to Gemini.

| | |
|---|---|
| 30% | Gemini portion of Hilo to Manoa DS3 circuit |
| 19% | Capital expenses for network equipment transferred to UH |
| 13% | Funding of UH staff position to support the network |
| 13% | Funding of Abilene access fees for UH, Gemini and other institutions |
| 12% | Hilo to Mauna Kea DS3 circuit |
| 5% | Capital expenses for network equipment to be used at Gemini |
| 3% | Maintenance contracts |
| 2% | Materials and supplies |
| 2% | AURA administrative fee |

Another issue which had to be resolved was where to locate the Island of Hawaii endpoint of the Oahu to Hawaii DS3. On Oahu, the clear choice was to terminate the circuit at the UH Information Technology Services (ITS) building on the UH-Manoa campus. But on Hawaii, two possible locations were the summit of Mauna Kea or in Hilo. By terminating at the summit, all participants in the Mauna Kea Observatories Communication Network (MKOCN) would have equal access to the service. This consideration comes about because, of the eleven observatories which which are part of the MKOCN, eight have (or will soon have) base facilities in Hilo and two have base facilities in Waimea. The VLBA operates their radio telescope remotely from New Mexico. By terminating at Mauna Kea, all parties have "fair access" to the link.

By terminating in Hilo, Gemini would have a critical connection to the next generation Internet which did not depend on maintaining services or equipment at the summit. Since Gemini is in the unique position of operating two telescopes from the headquarters in Hilo, we had concerns about equipment being inaccessible at the summit due to

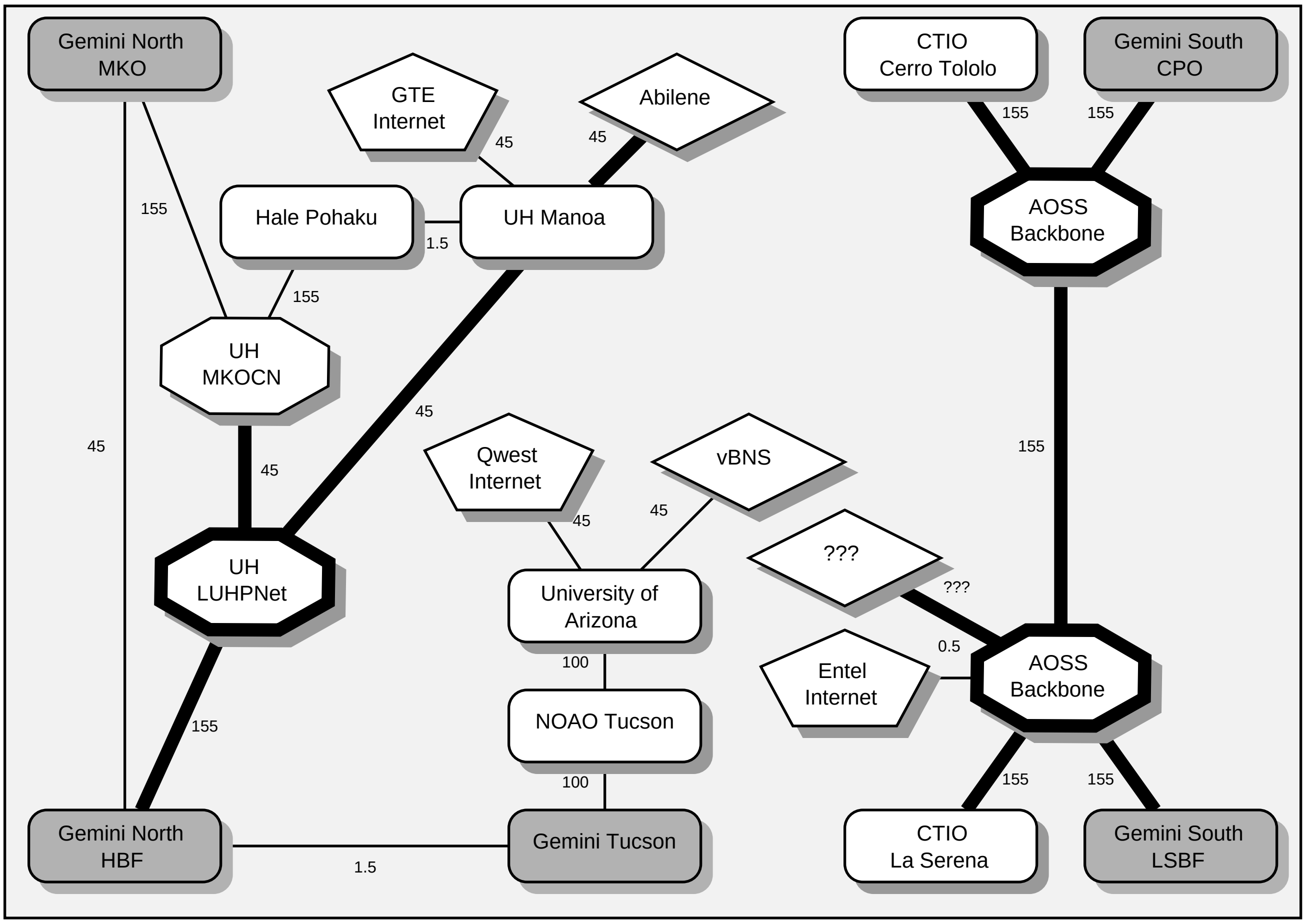


**Figure 2.** Network configuration after Gemini NSF grants.

inclement weather or unforeseen circumstances. Terminating in Hilo also means that the University of Hawaii-Hilo (UHH) and any future non-astronomy tenants of the UHH Research Park may also have access to this connection. And finally, after the two year grant period expires UHH may have installed a planned OC3 connection to UH-Manoa. We could then send traffic to Manoa over the UHH link and remove the Gemini link.

The agreed upon compromise was to terminate the circuit in Hilo, but to have Gemini fund a separate circuit from Hilo to the summit of Mauna Kea for the Waimea observatories to use for Internet traffic. At the end of the two year period, this topology will be re-evaluated.

As of February 2000, we have purchased all the capital equipment as well as materials and supplies. Two Cisco 7206VXR routers, two Cisco LightStream 1010 ATM switches and two Cisco Catalyst 2924 ethernet switches have been delivered. Numerous media convertors, fiber optic patch cables, fiber optic patch panels, Cisco interface cards, *et cetera* have been delivered. We have pulled fiber optic trunk cables between a number of buildings at the UHH Research Park. However, neither DS3 circuit has been installed. We are anxiously looking forward to using this new connection.

### 4.2. Chile Grant

Following the success of the Gemini North grant application, Gemini was strongly encouraged to submit a similar application for Gemini South. For this grant, we partnered with CTIO to install a shared backbone. By submitting a combined application on behalf of both Gemini and CTIO, we could each apply for US$350,000, or a total of US$700,000.

In preparing the application a few issues arose. One was whether to implement the backbone with fiber optic cables or with microwave radios. There was much discussion, but eventually we chose microwave radios. Another question was whether to install all the equipment with staff technicians or to require the selected vendor to supply a turn-key solution. Again, much discussion. We decided that we would require a turn-key solution, but that we would allow the vendor to subcontract some installation services back to CTIO if the vendor desired.

Installation and operation of a microwave system requires not only the cooperation of both Gemini and CTIO, but the Las Campanas Observatory (LCO) as well. There is no line of sight from Cerro Pachon to La Serena. There is a line of sight from Cerro Tololo to La Serena, but not to the AURA recinto. Due to the local topography, the microwave will consist of a number of segments. One segment will connect Cerro Pachon and Cerro Tololo. Another segment will connect Cerro Tololo with LCO headquarters. The final segment will connect LCO headquarters with the AURA recinto. Because the LCO headquarters are only a short walk from the AURA recinto, the equipment at LCO may be completely passive, acting as a reflector between Cerro Tololo and the AURA recinto.

LCO has agreed to allow AURA to construct and use facilities at their headquarters site such as tower, microwave dishes, support shack, *et cetera* at no cost. While LCO is not participating in the network connection at this time, they may join at a later date.

News that US$700,000 had been awarded by the NSF to Gemini and CTIO was rceived on 27 August, 1999.

The backbone will be operated by a newly created organization: AURA Observatory Support Services (AOSS). This is intended to be a group separate from both Gemini and CTIO which will operate on behalf of both observatories to provide some common administrative and technical services.

As of February 2000, the Request for Proposals (RFP) has gone out. Bids will soon be collected and evaluated, and the contract for the microwave system will be awarded. With the cost of the microwave system determined, the other aspects of the system can be purchased.

While the Gemini North grant was intended to establish a connection to the next generation Internet, the Gemini South grant was focused on establishing a solid internal network. In the North, we could lease a connection between HBF and MKO. In the South, there is no such possibility. Thus we had to create this connection ourselves. This leaves two open questions: How do we connect Gemini South to the next generation Internet, and how do we connect Gemini North and Gemini South?

## 5. SUMMARY

Gemini has been fortunate to receive these grants to improve our network infrastructure. In Hawaii, our grant together with a grant awarded to UH has allowed us to establish a connection to the next generation Internet. In Chile, our combined grant with CTIO will allow us to establish a high-speed backbone between our base facilities and our observatories.

These are significant steps toward the ultimate goal of connecting Gemini North and Gemini South to each other and to our scientific community. We are already working on plans to bridge this final gap.