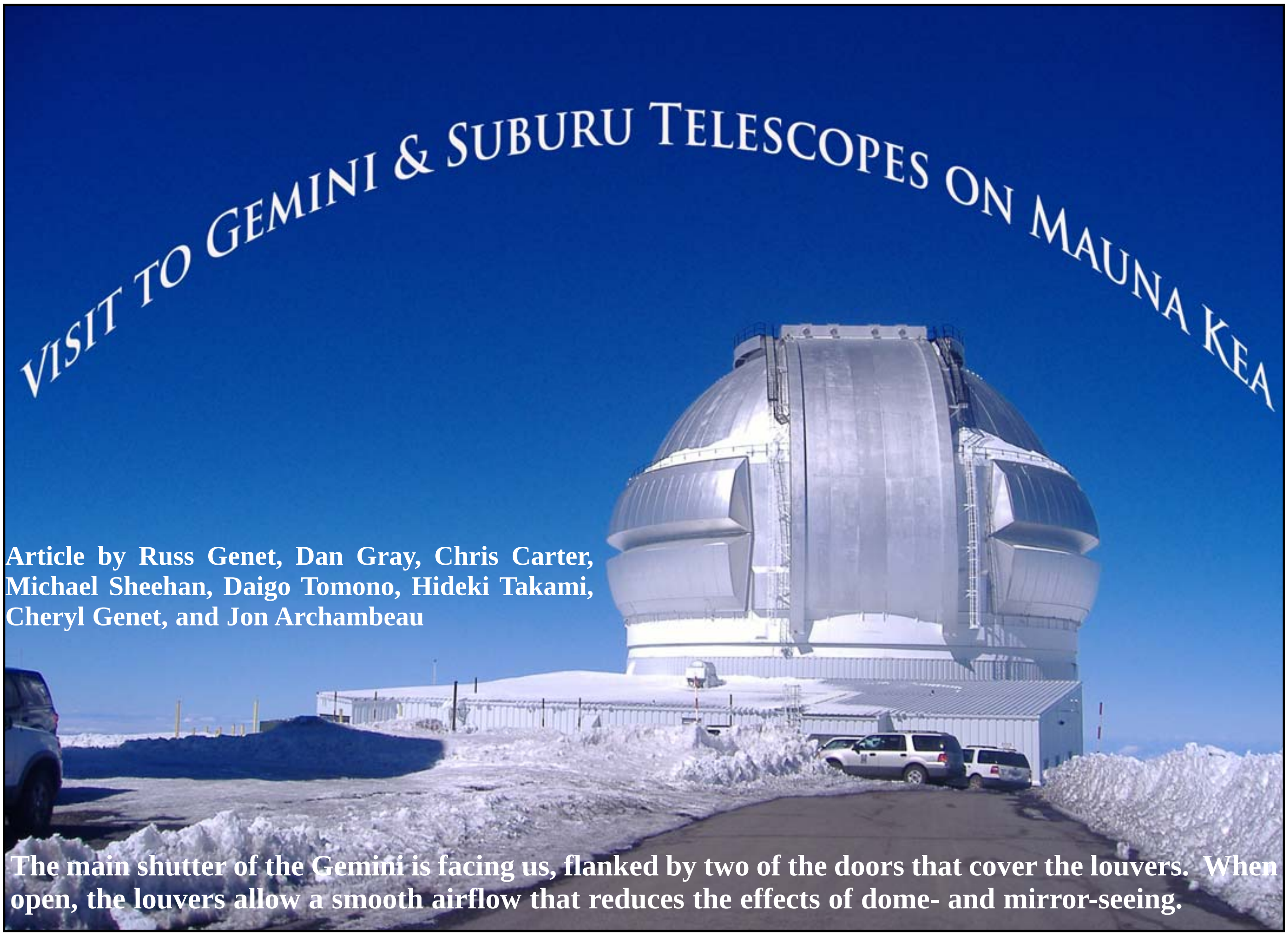
Visit to Gemini & Suburu Telescopes on Mauna Kea

Article by Russ Genet, Dan Gray, Chris Carter, Michael Sheehan, Daigo Tomono, Hideki Takami, Cheryl Genet, and Jon Archambeau



The main shutter of the Gemini is facing us, flanked by two of the doors that cover the louvers. When open, the louvers allow a smooth airflow that reduces the effects of dome- and mirror-seeing.

The 5-meter Hale telescope on Mt. Palomar was the largest equatorially-mounted optical telescope ever built. A motor moving at constant speed in a single axis allowed this giant telescope to smoothly track the stars. There are now some 18 larger telescopes. All of these larger telescopes employ compact, gravity-symmetrical altitude-azimuth (alt-az) mounts, which allowed them to be built at much lower cost. The catch was that these telescopes required constantly-changing drive rates in three axes: altitude, azimuth, and field derotation. This was not possible before the advent of reliable digital computers. Recently, alt-az digital telescope control systems have become so inexpensive that the alt-az revolution can now go in the opposite direction, from larger to smaller telescopes.

Astronomers (both professional and amateur), engineers,

Meeting participants at the Gemini headquarters in Hilo, left to right: Chris Carter, Mike Sheehan, Daigo Tomono, Hideki Takami, Doug Simons, Russ Genet, and Dan Gray.

Cheryl, Russ, Dan, and Chris stopped for leisurely lunch and altitude adjustment on the way to the summit. This facility at the 9000 foot level is a hotel and restaurant for all the astronomers.

Cheryl, Russ, Chris and Jon stand by Gemini's Cassegrain focus. One optical path is straight through to the bottom instrument behind Cheryl, while four other instruments are above

Dan examines the flex plate and azimuth high torque motor. Dan's cap helped keep him warm. The interior is kept at the expected nighttime temperature.

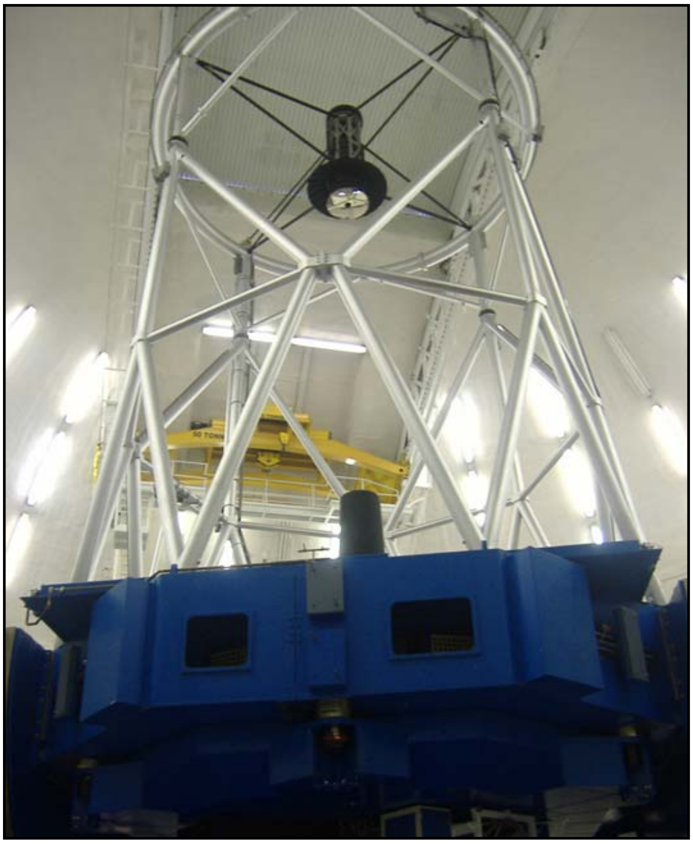
students, and smaller telescope manufacturers are working together in an informal group to develop economical research-grade alt-az telescopes in the 0.4 to 1.5 meter range. Large alt-az telescopes have pioneered many of the techniques that can now be applied to their diminutive cousins at greatly reduced cost and weight, thanks to advances in electronics and materials. A key element of this smaller telescope, alt-az developmental program is discussing technical aspects of the large mountaintop telescopes with the engineers who design and maintain them. They genuinely enjoy considering the technical challenges of applying what they have learned on a much smaller scale with greatly reduced budgets.

Large and small research telescopes are complementary. The larger telescopes, which are few in number, concentrate on fainter objects or on discovery surveys, while the growing army of smaller telescopes concentrates on brighter objects as well as follow-up time-series observations of newly discovered objects. By sharing large and small telescope design knowledge, we hope to develop 0.4 to 1.5-meter alt-az research telescopes that emulate their big mountaintop cousins at costs that will allow many small colleges and even high schools to acquire such modern research instruments.

Recently, two of the alt-az team members (Russ Genet and Dan Gray) met with Gemini engineers Chris Carter

***Below:** The elevation drive is similar to the azimuth drive, although smaller in scale. The end of the elevation sector can be seen at the lower right.*

***Right:** Dan (left) and Chris examine the control electronics for the secondary mirror. Both are control system experts and spoke at times in their strange language.*

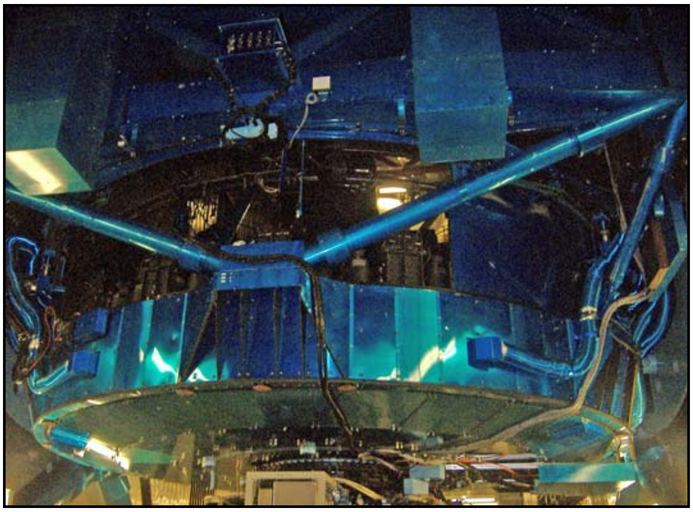


Left: The top end of Gemini's OTA. The 1-meter secondary is the small bright item in the middle of the secondary baffle, which was designed for infrared observations.

Above: View of Haleakala on Maui from Subaru. Haleakala and Mauna Kea were separated by a sea of clouds which drifted below the summits. They are even lower during the night thanks to an inversion layer.ration for the night's run. The snow removal team was dwarfed by the massive dome.

Below: Russ stands under the Subaru telescope beside the Cassegrain focus instruments. This is just one of the four focus positions.

Access to the Gemini telescope is via the tower on the left and an underground tunnel which leads to the control room in a separate building.



Subaru's primary mirror cell. The mirror was being uncovered as we watched, in preparation for the night's run. Its diameter is 60 times its thickness.

When the thin meniscus mirror is removed from the telescope and brought down to be recoated, it must be very carefully supported in this mirror transporter.

and Mike Sheehan and Subaru engineers Daigo Tomono and Hideki Takami in Hilo, Hawaii. A visit to the 8-meter Gemini and Subaru telescopes on Mauna Kea followed this meeting. Chris Carter guided Russ Genet and Dan Gray through Gemini, while Daigo Tomono guided them through Subaru. Cheryl Genet kindly took photographs throughout the Mauna Kea visit, and Jon Archambeau provided transportation and Gemini tour guidance. Our goal was to observe and discuss aspects of the Gemini and Subaru designs we might be able to transfer to smaller telescopes.

The Gemini telescope's instruments are all located at its Cassegrain focus. An instrument selector can rapidly switch the optical path between the instruments. This allows queued programs to dynamically adjust to observing conditions. Also, having all the instruments at the bottom end of the optical tube assembly (OTA) results in a low elevation axis location, which places the primary mirror well up in the dome where air flow from generously proportioned shutters helps eliminate mirror-seeing.

The Gemini telescope uses one stage of friction-drive reduction in azimuth. There are four pairs of two high-torque motors that drive a large-diameter azimuth disk. The motor pairs are fastened to substantial flex plates and pressed against the azimuth disk by hydraulic actuators. Position feedback is provided by a Heidenhain tape encoder and read heads, while velocity feedback is provided by tachometers. A key suggestion made by the Gemini and Subaru engineers during our meeting was that we add velocity feedback to our small telescope control systems.

The top end of Gemini's OTA consists of a two-bay truss. Single-bay trusses are appropriate for smaller telescopes. Interestingly, although the Gemini's top end, which supports its spiders, is a round ring, the Gemini engineers recommended that we use square top ends on our smaller alt-az telescopes. The spiders can then be put under considerable tension, placing the square under pure compression. This tightens up the entire top end of the telescope. But why doesn't the Gemini have a square top end? The straight top members would have been over 28 feet long, and buckling would

The entire Subaru building rotates on dozens of massive wheels. Russ gives perspective to their size.

The complex of walkways and machines below the Subaru telescope was an engineer's delight.

Dan and Jon listen in on the left, while Daigo and Russ discuss Subaru operations. The night operator on the right prepares the telescope for the night's run.

Looking from the Subaru telescope, we could see the nearest Keck telescope. The Canada France Hawaii telescope and Gemini are on the ridge behind.

have been a problem. Small has its merits!

Gemini's basic telescope control system is augmented with a tip-tilt secondary mirror and autoguider camera to keep stars centered in the instrument under use. The tip-tilt secondary handles the higher frequency disturbances caused by the wind, while the telescope control system takes care of tracking and lower frequency corrections passed off from the autoguider via a low-pass filter, thus reducing the range of corrections the tip-tilt secondary needs to make.

Needless to say, a 1-meter secondary mirror buzzing away at the top end of the telescope making corrections, not to mention providing "chopping" for infra-red (IR) observations, would have made a very good telescope vibrator were it not for a reaction mass that is moved exactly opposite to the secondary mirror. For our much smaller alt-az telescopes we are planning on using a deviator (wobble) plate. Interestingly, the 3.5-meter Canada France Hawaii Telescope (CHFT), which is right next door to the Gemini telescope, uses a deviator plate for its higher frequency corrections.

A laser can project a bright artificial star in the atmosphere's sodium layer about 60 miles above the telescope, very close to the object of interest. This artificial star is used to determine wavefront distortions with a Shack-Hartmann sensor. A high speed computer calculates corrections that are fed to a small deformable adaptive optics mirror at very high frequency to cancel out the distortions. Bright natural stars further away in the field cannot be used because of isoplanetism (uncorrelated motions), thus the need for the laser. Jon Archambeau trains and directs the visual, human aircraft spotters who keep a vigilant lookout during laser operation.

Daigo Tomono kindly led us through the Subaru telescope. Unlike Gemini, which has all its instruments at the Cassegrain focus, Subaru has a Cassegrain focus and two Nasmyth foci. Furthermore, the secondary mirror can be swapped out for a prime focus instrument. All these additional features require a very sturdy structure, so the Subaru telescope weighs more than the Gemini telescope.

Both the Gemini and Subaru telescopes use thin meniscus primary mirrors. The mirror blanks were cast at Corning from ultra low expansion (ULE) fused silica. Passive supports alone would have been inadequate for these thin mirrors, so their figures are fine tuned with actuators which actively apply forces to the backs of the mirrors. The Subaru mirror has a diameter to thickness ratio of 60:1. What was of interest to us was that once the necessary mirror force corrections for various elevations and temperatures were determined for Subaru, they were used for months in a table look-up fashion before they needed to be refined. This may be important for our larger-aperture small alt-az telescopes. We might use a thin meniscus mirror in our 1.0 to 1.5 meter telescopes with active control, and hope we could make calibration measurements off line and just interpolate from a table during normal operation.

Like all large modern telescopes, both Gemini and Subaru are operated from warm rooms. Remote observations in real time are possible with these and many other large telescopes. Queue scheduling allows observations planned out well in advance to be switched in or out as conditions dictate. A resident astronomer usually monitors the queue observations. Many smaller observatories now also support warm rooms, remote observing, and queue observing

As we left Mauna Kea, final preparations were being made for another night of observing at the top of the world. During our descent, we reflected on how some of the advances made by these mountaintop giants could be translated into economic improvements for our smaller, lowland telescopes.

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