BUILDING KECK

An Oral History

Between 1991 and 1992, the Caltech Archives conducted a series of seven oral history interviews with administrators, designers, astronomers, and managers from Caltech and the University of California (UC) to record the history and development of the W. M. Keck Observatory. Those interviews were published online for the first time in the fall of 2018.

Construction on the first of the two Keck telescopes began in September 1985 after a $70 million donation from the W. M. Keck Foundation; the Keck I telescope's first light occurred a little more than five years later, in late 1990. At the time of the interviews, a second Keck Foundation donation had made it possible to begin construction of the Keck II telescope, which would capture first light in October 1996.

To tell the Keck story, *Caltech* magazine turned to those oral histories, weaving one narrative from seven storytellers. The entire set of interviews may be found on the website of the Caltech Oral History Project. This is the first in a series of articles on the past, present, and future of the Keck Observatory and the science done there that will appear in Caltech's print and online publications.

THE STORYTELLERS
(in alphabetical order)

William Frazer, professor of physics at UC Berkeley, emeritus, UC's senior vice president for academic affairs during the construction of Keck I.

Jerry Nelson (BS '65) (1944–2017), project scientist for the W. M. Keck Observatory from 1985 through 2012, and principal designer of the 10-meter segmented mirrors for which Kecks I and II are known.

Gerry Neugebauer (PhD '60) (1932–2014), Caltech's Robert Andrews Millikan Professor of Physics, Emeritus, who played a key role in design and construction of Keck 1 as chair of the Division of Physics, Mathematics and Astronomy.

J. Beverley Oke (1928–2004), Caltech professor of astronomy, emeritus, who designed many of the instruments for Keck I.

Wallace L. W. Sargent (1935–2012), Caltech's Ira S. Bowen Professor of Astronomy, who had worked as director of Palomar Observatory and was involved, along with several others at Caltech, in working with the Keck Foundation to finance what would become the Keck I telescope.

Maarten Schmidt, Caltech's Francis L. Moseley Professor of Astronomy, Emeritus, who helped decide upon the segmented-mirror design created by Jerry Nelson for the Keck telescopes.

Gerald Smith, formerly with JPL, who was the project manager for the W. M. Keck Observatory's telescopes from the beginning of the project until his retirement in 1996, soon after the dedication of Keck II.

THE BEGINNING:

"Here's how you weld."

Frazer: In '83, David Gardner became president [of the UC system] and … I became the university's principal administrator on the telescope project.

Neugebauer: I was fairly deeply involved in the beginning. I was the director of Palomar, and I basically took two years off to run IRAS [InfraRed Astronomical Satellite]. And when I came back from that, there was a question: "What should we do?"

Nelson: I met [Gerry] Neugebauer and [Robert] Leighton, my TAs as a sophomore [at Caltech], and they invited me to work for them. It turned out that they were involved in infrared astronomy, and in particular, they were involved in building a 60-inch telescope to do an infrared sky survey on Mt. Wilson. … They were going to build everything themselves with a spun epoxy mirror, and they got me involved in practically every aspect of designing and building this thing. I remember the day they hired me. Leighton dragged me into the shop and walked me into one of the rooms and said, "OK, see all these bars of steel? I want them all welded together, and here's how I want them done." And he pulled out a welding torch and he said, "Here's how you weld." He gave me a five-minute lesson and said, "Here." *[Laughter]*

Oke: We already … had the biggest telescope in the world, and we thought we were doing about as good a thing with it as anybody could. But I think we also realized … that we needed more "oomph," we needed more collecting area, if we were going to really keep up … our leadership role in astronomy.

Sargent: I wrote a memo to [Jack] Roberts [who was then Caltech's provost] on the 18th of March, 1980, in which I said, "It's now thought to be technically possible to construct ground-based optical telescopes in the 10-to-15-meter range, using thin, segmented primary mirrors and active optics. There are plans to construct such telescopes by the late 1980s. One of these schemes, a 10-meter telescope, is being pushed by the University of California, with some input … from Caltech." We actually had a few advisers on their scheme. "We should seriously consider becoming a major partner in the UC scheme if we are not to fall behind in the late 1980s."

Upper left: Jerry Nelson (far right) and friends appear atop a full-sized prototype of the supporting frame for a mirror segment. Right: The Keck telescopes atop Maunakea.

PARTNERING:

"Having the money is all the difference."

Schmidt: Caltech was asked [by UC] whether we wanted to be a one-quarter partner, which started things on a very much more definitive course.

I think it was sometime in August 1984, or soon thereafter, we essentially settled on three scenarios of how things could be handled. And one would be that while we would build the telescope on Maunakea, the University of California would find enough money to build one in the Southern Hemisphere, and there would be cooperation, and the design would be the same. The second option was that, near the [Keck] telescope on the same mountain, another one might be built by the University of California, and [we] would do interferometry between the two and further cooperate. And a third option essentially came down to this, Caltech would provide the funds to build the telescope, and the University of California would bring in enough funds to run the installation for a considerable time, which turned out to be 25 years. Well, as we know, the final option was the one that became operative.

Smith: When the Keck Foundation and Caltech came in, I saw this as a real positive development, because I felt that the entry of Caltech would make it a much stronger operation. The funding was, of course, the key thing; having the money is all the difference.

So Caltech just breathed new life into it, as far as I was concerned.

WHERE TO PUT THE TELESCOPE?

"Or you can go to an island."

Neugebauer: The sites that are good for astronomy turn out to be sites that are high, or near water, so you have very smooth air flowing over it. That's why the good sites are here in California [and] in Chile. Or you can go to an island, and you have the wind blowing over the island in a nice smooth way.

Sargent: There'd been telescopes [on Maunakea] since … the late '60s.

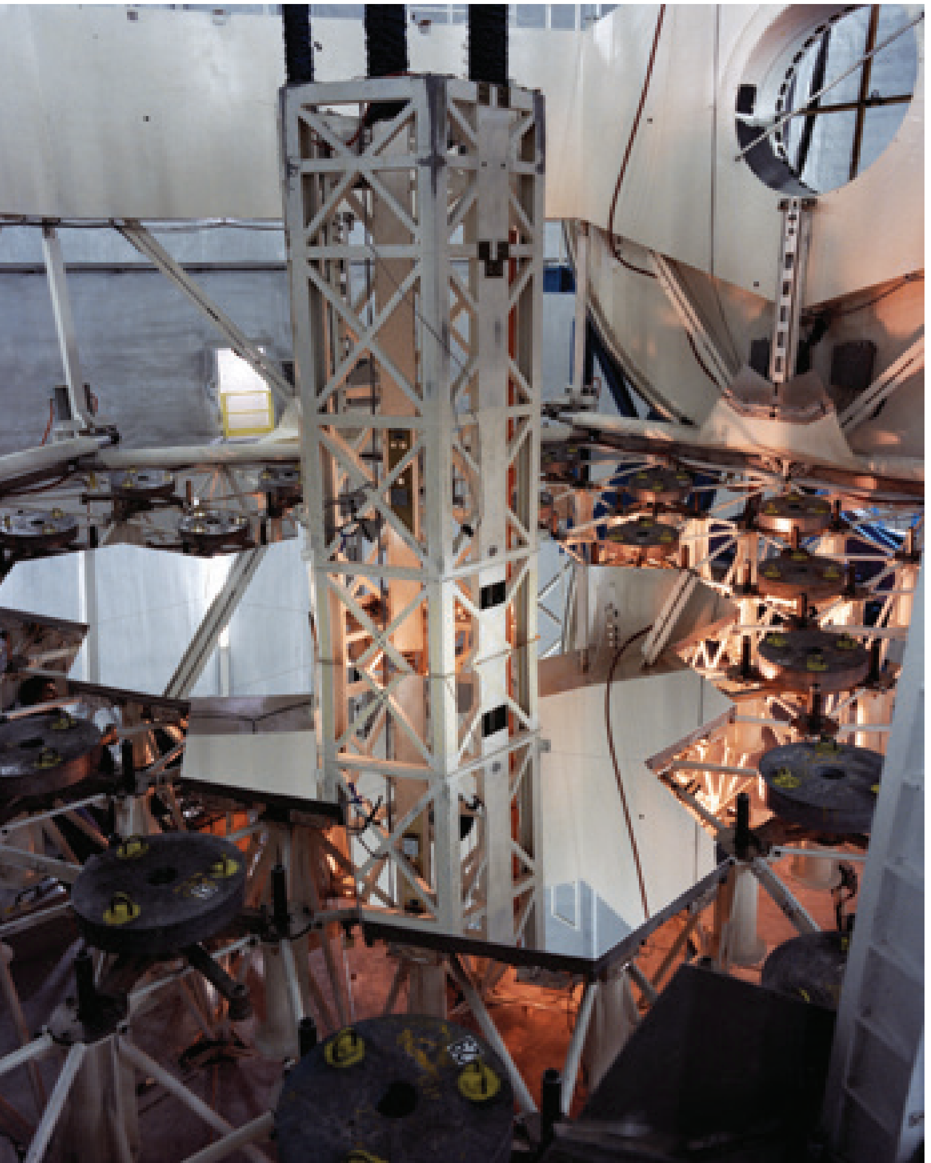
Schmidt: At that time, the University of California people, I think, had already settled on Maunakea, and we liked that very much: almost no light pollution, very high, and so on.

SOLVING PROBLEMS:

"It's a very clever idea."

Sargent: There were two competing designs [for the mirror], over which they had a shootout. One design was to have a single, very thin piece of glass that was flexible, the so-called rubber mirror, and adjust it with active controls from the back. The other was [Jerry] Nelson's idea, which was to have a segmented mirror in which there would be 36 hexagonal solid pieces which would be adjusted, but you wouldn't adjust the whole. It wouldn't be a complete surface; there would be cracks in it.

Nelson: In 1980 [or] probably the end of '79, when this committee was going to meet, there was a group of six or seven people on this committee, and we presented reports to them, both written and oral. … And after they reviewed it and talked to us at length, they ended up saying the segmented-mirror telescope was the way to go.



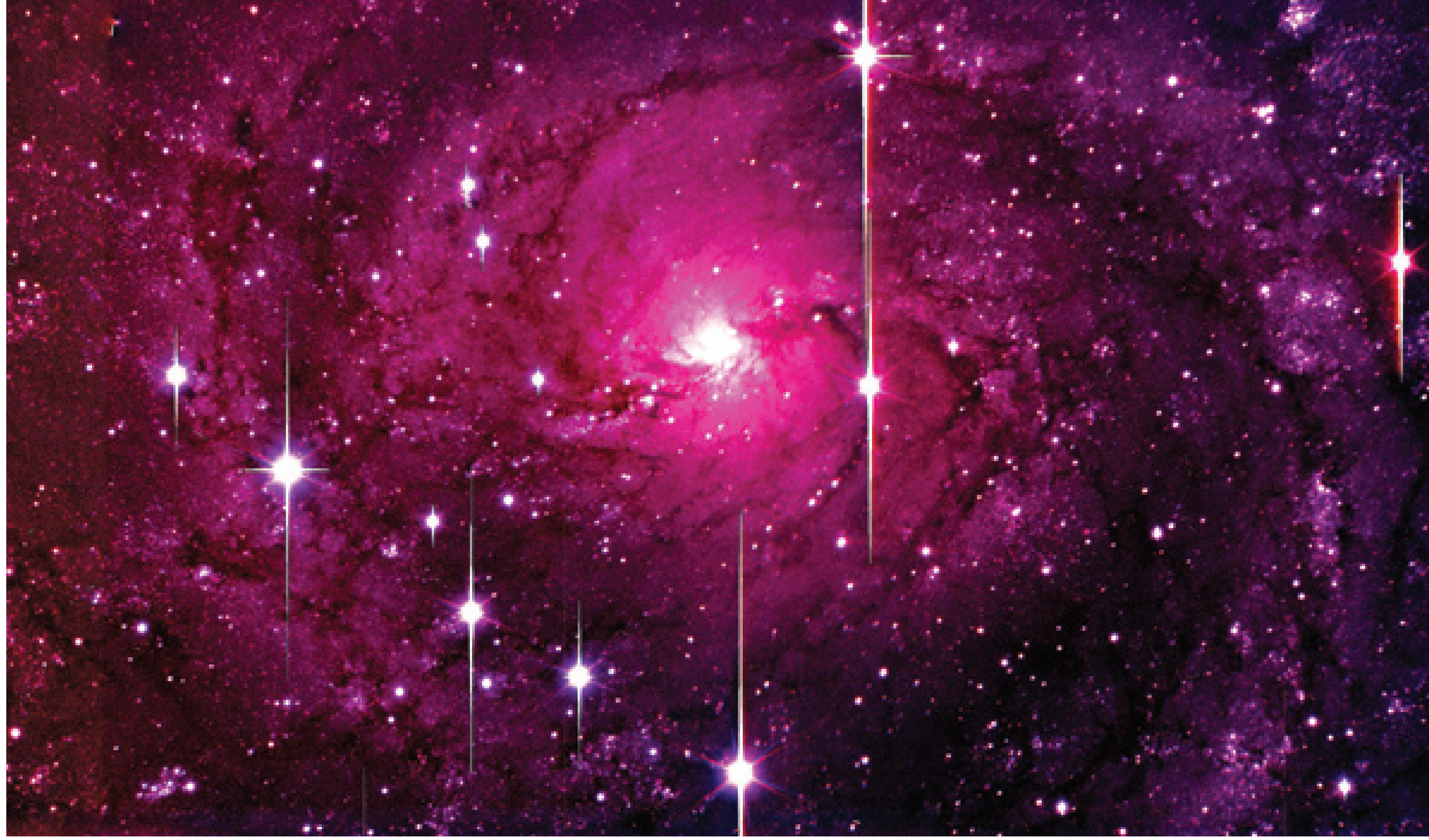
Early on, not knowing much about how you fabricate optics, I just sort of thought you take these off-axis mirrors and you get them polished somehow. And as I looked into that, I realized that, "No, wait a minute, polishing is not like machining metal. It's an art, not a science or even a craft." *[Laughter]* And I'd talked to people who'd polished optics, and they said, "Oh, no. We don't know how to do that. That's hard." … And I realized that this was a real issue, this wasn't a minor matter that we could solve someday in the future. It was a fundamental stumbling block, just as important as the active-control system.

Neugebauer: How do you make 1.8-meter mirrors inexpensively? Basically, the mirrors have to be in the form of a parabola after they're assembled. But it's much easier to polish them as spheres. So, what you do is you take the piece of glass and "stress polish" it. You bend the glass with weights along the edges, in just the right shape, [and] you polish that into a sphere. Then, when you release the weights, it springs back to the right shape. It's a very clever idea. It was Jerry Nelson's idea. That has turned out to work.

[Another] big technical problem, which turned out to work relatively easily, was to make all the mirrors play together. That was demonstrated on nine mirrors; they could make nine mirrors all point together and act as if they were one big mirror.

Nelson: When I did the calculations, I realized that with segments, you put them on some kind of structure. It's going to deform by such a large amount that there's no way you can just position them carefully and they'll stay where they belong. … I realized we were going to have to have some sort of active-control system.

Schmidt: The thing that struck me as something that went particularly well was the alignment system of the segments. That was, I think, only first tested just a little under a year ago, last March or April 1990 or so, close to first light. And when that system was turned on to align the first nine segments, the noise in the alignment was on the order of 15 nanometers, whereas when the dome was rotating, it became on the order of 40, and that was the first result, which was well within the requirements. And that's remarkable, because people in the community who had been following all this had been most worried about, or critical of, the claims made by Jerry Nelson that you can align these segments and then it's as good as if it were one surface. … Now that doesn't mean that it's easy. *[Laughter]* Jerry Nelson somehow did it particularly well.



Left: Nine of Keck's segmented mirrors. Upper right: Galaxy UGC 2847 as seen by Keck.

And then, the development of lightweight mirrors … opened the possibility of having telescopes that were very considerably cheaper per unit area than they used to be, by a factor of probably 5 to 10 or so. … I'm sure that otherwise the Keck Telescope would have cost between a half billion and a billion dollars or so.

WHAT'S NEXT?

"That's where the Keck, I think, will be priceless."

Oke: Well, the first things we will do when we put on the spectrograph, which we're designing, are pretty simple things. We'll take pictures that are pretty, obviously, spectacular. [They are] nice to look at. … They'll be just single objects initially, or a galaxy sitting on a single slit. And then as things start to get working better and better, you try long-slit kinds of things, and then you start multi-slit things, and then you try fainter and fainter things.

Schmidt: That's where the Keck, I think, will be priceless. It will really allow us to do things with distant galaxies that you now wouldn't think of.

Neugebauer: I would try and look at the center of the ultra-luminous galaxies. There are a series of galaxies that have a hundred to a thousand times more energy than the galaxies we know about. I would try to look at those and really study what makes them tick.

Oke: The second Keck has always been sitting there as a possibility. I don't know, for instance, whether this second telescope was something [Howard] Keck had talked about. But the rumors were around that he had talked a bit about the possibility of there being two. And in the early UC combination, there was talk about two. So this idea of a second Keck had always been in the deep background.

Nelson: It has sure been an interesting project. [C]

The W. M. Keck Observatory is home to the world's most scientifically productive optical and infrared telescopes. The Keck I telescope began its scientific observations in May 1993; Keck II saw first light in October 1996. Each telescope weighs 300 tons and operates with nanometer precision; each has a primary mirror composed of 36 hexagonal segments that work in concert as a single piece of reflective glass. The observatory was made possible by the financial support of the W. M. Keck Foundation.