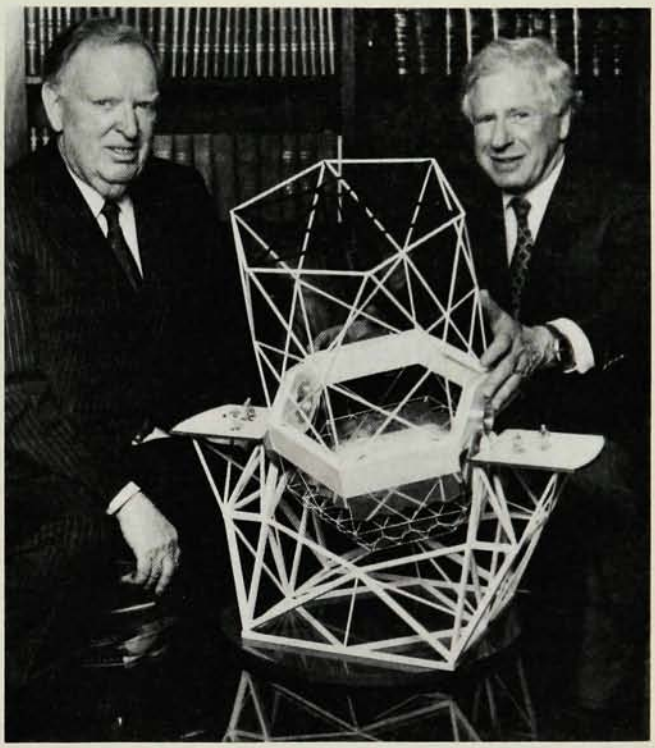
Keck Foundation offers Caltech $70 million for 10-m telescope



Model of telescope to be built with segmented-mirror technology on Mauna Kea in Hawaii. The model is flanked by Howard M. Keck, chairman and president of the W. M. Keck Foundation (on the left), and Marvin L. Goldberger, president of Caltech.

For California astronomers and university administrators, 1984 ended with a holiday season that was exciting, even suspenseful, and finally festive. But it was not exactly relaxing. Even after most other people were done with their celebrations and the gift wrappings were in the trash, California's astronomers and administrators were still peering up their chimneys, wondering whether Santa Claus was indeed going to come through with what was rumored to be a gift of unprecedented size and significance. It was only as the new year began that the good news was confirmed at last—and even then, some questions remained.

At a press conference in Pasadena on 3 January, Caltech president Marvin L. Goldberger announced that the W. M. Keck Foundation of Los Angeles was proposing to give the university $70 million to build a 10-meter segmented-mirror telescope on Mauna Kea in Hawaii. The technology for the telescope has been developed at the University of California's Lawrence Berkeley Laboratory, and the University of California will jointly operate the telescope with Caltech.

If all goes according to plan, the telescope will have a larger collecting area than any existing instrument and might be the world's largest telescope for a decade or more. It would be four times more powerful than Caltech's 200-inch telescope on Palomar Mountain, which has been the world's premier telescope since it was constructed in 1948. As Goldberger, a well-known particle physicist, noted at the press conference, the rather unsuccessful 6-meter telescope that the Soviet Union completed in 1976 has "not produced a wealth of astronomical information."

A stitch in spacetime. Applauding the "vision" of the Keck Foundation officers, Goldberger said that the proposed 10-meter telescope would enable astronomers to see billions of years farther into the universe.

Astronomers making use of the Palomar 200-inch telescope can look out to a distance of roughly 8 billion years, Goldberger observed, but using the proposed 10-meter instrument, they will be able to see back about 12 billion years—just a few billion short of the estimated age of the universe.

Speaking to the question of what prompted the W. M. Keck Foundation to propose what apparently is the largest private gift ever made for a scientific project, Howard B. Keck, the foundation's president, said that the foundation "had been interested in making a significant gift to further the interests of science and the interest of mankind in learning why we exist." No doubt, strong and long-standing ties between the Keck Foundation and Caltech help account for why this particular scientific project was singled out for unequaled largesse. Howard Keck is a Caltech trustee, as was his brother, the late William M. Keck Jr. Their father, William M. Keck, was an oil entrepreneur who established the foundation in 1954.

The application of a daring and innovative technology to a project of broad importance would appear to be very much in the spirit of William Keck, a successful wildcatter who was a pioneer in applying scientific techniques such as reflection seismography to petroleum exploration. Keck built his Superior Oil Company into the world's largest independent producer of oil and gas, and he left a foundation and trust fund with assets that currently total around $500 million. In his honor, the facility housing the proposed 10-meter telescope on Mauna Kea is to be called the W. M. Keck Observatory.

'An equal partnership.' For many of the reporters at the press conference on 3 January, the disclosure that the telescope was to be named after Keck was surely a much greater surprise than the news of the telescope itself. It had been well known for years that California astronomers hoped to build a 10-meter telescope, but the general expec-

0031-9228 / 85 / 0200 71-06 / $01.00

tation was that the University of California would take the initiative, using a $35-million bequest it supposedly had received from the estate of Marion Hoffman to leverage more money from other private donors, foundations or academic institutions. If Caltech joined the project, it was expected to join as a kind of junior partner in a telescope named after Hoffman.

Instead, Caltech has emerged as the principal owner of the telescope and a full partner in its operation. A nonprofit corporation with equal representation from Caltech and the University of California is to be established to direct the construction of the telescope and to manage the Keck Observatory. The $70-million grant from Keck is expected to cover most construction costs, which are estimated at around $85 million. The nonprofit corporation will decide how to cover construction costs that exceed $70 million. The University of California will cover all operating costs for some period of time. This unusual arrangement originated in a series of negotiations last year between a team of University of California officials headed by physicist William Frazer, a university vice president, and a Caltech group headed by Rochus E. Vogt, who is likewise a physicist and university vice president, as well as Caltech provost.

In the negotiations last fall, it appeared to be Frazer's aim to bring Caltech into what he referred to as an "equal partnership" in the project. If these plans had come to fruition, the University of California presumably would have been seen as the prime mover behind the project, but Caltech would have gained the not inconsiderable advantage of being able to use and control use of the new observatory on an equal basis.

At just this jucture, early last November, the negotiating situation changed dramatically with two new developments. The University of California ran into some kind of difficulties with its donor, and it became known that Caltech was involved in very delicate negotiations that might lead to an extremely large donation for the telescope project. Obviously enough, if such a donation materialized, Caltech might be tempted to cut the University of California out of the project altogether and build the 10-meter telescope as an exclusive Caltech property. Frazer and Vogt say that negotiations never stopped, however, and that their discussions remained gentlemanly to the end.

Hoffman estate. Through November, University of California officials continued to deny all specific rumors about problems with their donor, but it was apparent from their reluctance to discuss the matter that there was indeed some kind of difficulty.

Some six months earlier, the University of California had announced its receipt of a $36-million deathbed bequest from Marion Hoffman, who wanted to memorialize her husband, the late Maximilian Hoffman. Her husband had been an importer of foreign cars, and while he had no particular interest in astronomy, he did take a strong interest in advanced technologies. After Marion Hoffman's death in December 1983, two foundations were established to carry out the terms of her will, with a sister and a close friend playing key roles in each.

According to Frazer, Mrs. Hoffman's will contains a "non-binding statement" of her desire for money from her estate to be used to support the construction of a large telescope. Apparently some hitch developed in the execution of this intent, but even at this writing, Frazer remains unwilling to specify what problems arose.

At the press conference on 3 January, when University of California president David P. Gardner joined with Goldberger to announce the Keck Foundation donation, it remained unclear whether Hoffman money would contribute in any way to the project. The University of California confined itself to saying that the question of the Hoffman estate's possible participation would be settled by 1 March 1985, when Caltech and Keck are to sign a final agreement.

The University of California took care to remind the audience at the press conference that Keck's gift to Caltech could be attributed, ultimately, to efforts by the University of California to find funds to match the Hoffman bequest. The University of California said that Mrs. Hoffman had been "interested" in the telescope project and that she had discussions with university officials, which "after her death culminated in a gift of $36 million from the charitable entities established pursuant to her will."

One possibility, which received serious discussion in negotiations between Caltech and the University of California last fall, would be to build a second telescope. The second instrument could be but would not have to be a clone of the first. The two telescopes could be used independently (to relieve the large backlog of requests for viewing time); together, with superimposed images; or as an infrared interferometer.

In early January, Frazer seemed hopeful about the possibility of building a second telescope to match the Keck instrument. "I couldn't really speculate on that, but it would be a very nice outcome," Frazer said. Vogt said that Caltech remained very interested in the idea of building a second telescope. The provisional agreement between Caltech and the Keck Foundation requires the site of Mauna Kea to be prepared to accommodate a second telescope, which—if built—would be about 100 meters from the first.

Keck conditions. The Keck Foundation's agreement with Caltech requires three conditions to be met by 1 March 1985, when a final agreement is to be signed:

- completion of a technical feasibility report
- negotiation of a satisfactory agreement between Caltech and the University of California
- conclusion of a satisfactory agreement between Caltech and Keck.

Officials at Caltech, the University of California and Keck unanimously claim that these three conditions are mere legalities, and of course everybody who has the advancement of astronomy at heart fervently hopes that they are right. But then, everybody also knows that the 10-meter telescope project already has had a difficult history and that future success cannot be guaranteed.

The condition that Keck and Caltech negotiate a satisfactory agreement should present no difficulties, assuming that all other problems are solved. But the agreement between Caltech and the University of California will be a trickier matter, though Vogt and Frazer both say that all issues have been thoroughly aired and that no insurmountable obstacles have appeared.

One of the most important unresolved issues concerns the period of time in which the University of California will cover all operating costs of the Keck Observatory. As of the beginning of January, a careful estimate of the operating costs had yet to be made and it was not known, for example, what kind of arrangements the two universities might make for other parties to obtain viewing time at the observatory. Frazer guessed that the operating costs might come to about $2.5 or $3 million a year.

Another question is whether or not both institutions will be entitled to claim ownership of the telescopes. Caltech is to be legal owner of the instrument and will lease it for $1 a year to the nonprofit corporation it is to comanage with the University of California. The agreement of principles between the two universities opens with a sentence saying that they "will be equal partners in the construction and operation of an astronomical facility."

Technical review. Last fall, when the University of California was still hoping to be first among equals in the construction of the 10-meter telescope, a committee was established to report

Demonstration instrument built at Lawrence Berkeley Laboratory to test the actuator and sensor systems for a segmented-mirror telescope. At the left of the mirror segment is Jerry Nelson, leader of the team that built the Technical Demonstration Telescope, and at the right is his co-worker George Gabor.

on the technical merits of the proposal for the 10-meter telescope. The chairman of the committee is Robert J. Parks, deputy director of the Jet Propulsion Laboratory, and it includes a dozen experts from around the country. The committee is to meet at the end of January and issue a report a week or two after that.

No formal relationship exists between the review committee and the technical report that is to be written for the Keck Foundation by a Keck official by 1 March. But it stands to reason that the Keck official will want to take the views of the review committee into account.

The committee's charge is to determine whether the segmented-mirror technology "is sufficiently well explored" and whether the "telescope as projected makes sense," Harold Ticho said last November. Ticho, a physicist at the University of California, San Diego, heads a committee that has been responsible since 1980 for monitoring the development of the segmented-mirror technology, and it was his committee that appointed the peer review panel. (For a detailed description of the technology, see PHYSICS TODAY, August 1981, page 17.) Selections for the peer review committee were made in collaboration with Caltech astronomers, and the letters of appointment went out with signatures of Edward C. Stone Jr, chairman of the division of physics, mathematics and astronomy at Caltech, and Ticho.

At the end of December, Ticho said that "we don't expect the review to say this is a lot of nonsense," and Parks emphatically agreed. Parks already had the technical proposal for the telescope in hand at that time, and he declared himself highly impressed with the care with which it had been written, its detail and its clarity. His expectation was that the committee's report would be largely confined to suggestions for alternate solutions to certain technical problems and, possibly, dual approaches in certain cases.

When asked what accounts for their confidence in the segmented-mirror approach, California astronomers regularly express confidence, first and foremost, in Jerry Nelson of Lawrence Berkeley Laboratory and the astronomy department of the University of California, Berkeley. During the past three years, Nelson's group has built a prototype that consists of a single 1.8-meter hexagon linked to part of a second hexagon called a "reference segment." The prototype was built to test the sensor and actuator technology for the mirror—it does not look at the sky, and in contrast to the segments that are to be used in the 10-meter telescope, its optical surfaces are spherical, not parabolic.

On the basis of successful work with this prototype and the development of innovative "stress polishing" techniques for the mirror segments, Nelson and his team consider a full-scale 36-segment 10-meter telescope ready to be built. Each segment of the telescope would rest on three actuators, which would modify their tilt 300 times per second.

Asked about the possibility of scaling problems in going directly from a one-and-a-fraction prototype to a 36-segment mirror, Nelson said, "The whole philosophy is that it is just like paving your bathroom floor." The scaling problems are much less risky than with one mirror, he argued, "because you're doing the same thing over and over again." With more time, he said, he might prefer to build first a seven-segment mirror and then maybe an 18-segment device. "But we don't have a lot of time," Nelson said. "We want a working telescope now."

Nelson is a Caltech graduate, and according to Vogt, Caltech astronomers are well acquainted with him and his work. Vogt noted that Robert B. Leighton, in particular, has systematically evaluated alternative approaches to new telescope technology. About two years ago, Vogt said, Caltech informally charged a group that included Leighton with the task of thinking constructively about what the university might do to "maintain its preeminent position in world astronomy."

Leighton served last year on a technical evaluation panel that reported to a science advisory committee of the National Optical Astronomy Observatories. The NOAO committee was to issue a recommendation on what kind of technology should be used in the construction of a 15-meter new-technology telescope (see PHYSICS TODAY, January, page 91). That committee compared the segmented-mirror technology with a multiple mirror telescope using an array of the honeycomb mirrors that are being developed by a team centered around Roger Angel at the University of Arizona's Steward Observatory. The committee opted in favor of multiple-mirror technology for the 15-meter telescope, but the decision was considered very close. Moreover, the principal mission of the committee was to determine what kind of telescope would do the most valuable scientific work at a national facility designed to provide for very wide and flexible access. Technical assessment of the two telescope technologies was an important but secondary task of the committee.

The national new-technology telescope is to be a scaled-up version of the multiple-mirror telescope currently operated by the Smithsonian Institution and the University of Arizona. It will be a multiple-mirror telescope consisting of four 7.5-meter honeycomb mir-

rors. The mirrors yield separate images that must be combined by a prismatic or computerized system. A segmented-mirror telescope, in contrast, acts as one mirror with a single focus.

Great leap forward? Robert Kirshner, chairman of the University of Michigan astronomy department and a member of the NOAO science advisory committee on the new-technology telescope, has referred jokingly to Angel's honeycomb-mirror technology as "the great leap backward." Kirshner alludes to the fact that Angel's technology is a greatly improved version of the honeycomb mirror employed in the 200-inch telescope on Palomar Mountain.

By the same logic, Nelson's technical proposal deserves perhaps to be called "the great leap forward." Robert D. Gehrz, the University of Wyoming astronomer who was chairman of the NOAO science advisory committee on the new-technology telescope, characterized Nelson's proposal as "quite a daring step" when he was informed of the Keck Foundation grant at the beginning of January. Gehrz was delighted to hear the news and wished all power to the California astronomers, but at the same time, he noted that the NOAO committee's recommendations were based on considerations connected with technical risk as well as scientific and institutional factors.

In the section of the report on technical risk, which has received the unanimous endorsement of the 12-person committee, it is stated that the existence of a working prototype for a multiple-mirror telescope was an important factor in its favor. At the same time, the committee stressed that its recommendation was specific to the 15-meter telescope and it characterized California's plan to build a 10-meter telescope employing segmented-mirror technology as "healthy."

Even so, some of the committee's statements about a proposed 60-segment 15-meter telescope would seem to apply with almost equal force to the proposed 36-segment 10-meter instrument. Specifically, the report said:

▶ Since the SMT [segmented-mirror telescope] must control 60 relatively small optical subsystems to produce high quality images, frequent reference to stellar standards appears impractical and a very strong emphasis will have to be placed upon standardization, stabilization and computer modeling of the behavior of the mirror position sensors and actuators. Demonstration of a prototype system would do much to allay the reservations about the effectiveness of such a system. The ultimate success of the SMT system will depend to a great degree upon how well systematic but nonrepeatable errors propagating through the system can be damped. In general, the technology for achieving the desired goals with the SMT concept appears to be the more challenging. . . .

▶ Several failure modes may be present with active optics control, but the most severe would be a fundamental failure to successfully implement the ability to ever maintain the images from all subsystems coincident for any reasonable length of observation time. This would almost certainly be a terminally serious failure for an SMT. . . .

▶ Bend-and-polish experiments have revealed a distressing degree of segment warpage when the excess glass is cut away after figuring of the untrimmed blank. An untrimmed blank must be used to minimize turned edge effects. This could represent a significant problem for SMTs. . . .

Alluding to the problem of warpage when the edges are trimmed from the round polished mirror to shape a hexagon, Leighton of Caltech said that Nelson's group had come up with a working solution, which is simply to compensate for bending by attaching springs to each segment. While this might seem like a "band-aid solution," Leighton said, "it actually works surprisingly well." Leighton conceded that there was some "undercurrent of doubt" on the science advisory committee about whether a mirror with so many segments would stabilize, but the "servomechanism experts on the committee said it would work like a charm following moments of adjustment" after being turned on.

Leighton said that he leaned toward the multiple-mirror technology when he started serving on the technology evaluation panel, but that he ended up deciding the segmented-mirror technology was "at least as good."

It is the Nelson group's repeated success in devising neat solutions to expected and unexpected problems that gives Leighton and many other astronomers confidence in the prospects for success. Still, some skepticism remains, especially among astronomers in the Rocky Mountain states who have their hearts set on development of the Angel technology and who fear that efforts to obtain Federal funding for the 15-meter telescope may be jeopardized if California proceeds successfully with its project.

Jacques Beckers, associate director of the National Optical Astronomy Observatories in Tucson, where he is responsible for planning advanced research and development, notes that the techniques for manufacturing the mirror segments are not fully developed. (Nelson and his colleagues currently are reviewing a number of proposals from US companies to manufacture the mirrors, and the glass is to be poured by a company in West Germany, Schott Optical Technologies.) Beckers noted that researchers at Kitt Peak had experimented with manufacturing parabolic segments and that a report on their conclusions was currently being prepared. Beckers said it was clear that Nelson's bend-and-polish techniques worked "with some precision," but it is not yet completely clear just how much precision one can achieve with the techniques.

Angel expresses admiration for Nelson, whom he refers to as a "very clever fellow" with a very competent technical group" that is "full of enthusiasm." But he thinks that they have "set themselves a hard task." When Nelson's group started to work on the prototype, Angel says, there did not seem to be a way of casting single-piece mirrors with a reflecting area bigger than five or six meters. "But now that we can do it," Angel says, "it seems the more straightforward way to go."

How many telescopes? Virtually all the astronomers associated with the segmented mirror and national new technology telescope projects have adopted a position of surface solidarity with each other's projects. That is, almost all of them express the view that both the 10-m and 15-m telescopes are needed, and almost all say that the honeycomb-mirror and segmented-mirror approaches are about equally deserving of development.

Not far below the surface, though, is a widespread feeling that it may not be possible to build two large new telescopes before the turn of the century. If California proceeds with its project on schedule, the feeling is that it may be very difficult or impossible to persuade Congress to put up more than $100 million to build the national new-technology instrument. On the other hand, if the California project is delayed by unforseen difficulties, it may die a slow death as the national telescope project gets underway.

Aggravating the situation are several plans by foreign governments to build large new telescopes, the latest of which is a Japanese proposal for a 7-m instrument on Mauna Kea, where it would join a telescope built by France and Canada, an 88-inch instrument operated by the University of Hawaii, a NASA infrared telescope, a British infrared telescope, and a 15-m instrument England and Holland are building for millimeter radiation. West European countries are discussing plans for an array of four new telescopes in Chile, and Soviet astronomers

are talking about a 25-m optical telescope.

Among astronomy officials at NSF, there is concern about the growing public perception that a great many large-aperture telescopes are in the works, which could easily lead politicians to ask why the US government should fund construction of instruments when American astronomers can just as well work at somebody else's facility. Needless to say, the same kind of thinking could infect private donors and foundations as well.

In addition to the new very large telescope projects, plans for several large telescopes also are being developed, and this too could affect public perceptions. Astronomers at the University of Texas have been trying hard for some time to raise money for a telescope using a 7.5-meter Angel mirror. It is generally assumed that the University of Arizona will be very eager to build a large Angel telescope as well.

All these plans are likely to be affected for better or worse by the progress Caltech and the University of California make in satisfying the conditions set by Keck. If California proceeds successfully with construction, some donors undoubtedly will be inspired to support competing or complementary proposals, while others may conclude that additional support would be superfluous.

In any event, construction of the California telescope will realize a dream California astronomers have had for some 20 years. The University of California began to explore prospects for a large new optical telescope in 1965. In 1970, the Regents allocated $0.5 million for the development of a proposal for a telescope that was to be built on Junipero Serra Peak in the coastal ranges near Monterey. The site of the proposed telescope was changed to Mauna Kea in 1978, and in 1980, the decision was made to proceed with construction of a segmented-mirror prototype. Frazer says that the University of California has spent nearly $7 million already on the development of an advanced telescope concept.

No doubt, the University of California astronomers and physicists would have preferred to take the lead in constructing the 10-meter telescope, but after the difficulties encountered last fall, they are relieved and pleased to be included as equal partners. Speaking at the press conference in Pasadena on 3 January, David P. Gardner, president of the University of California, said that "our collaboration with Caltech represents a unique combination of institutional and scientific talent of two distinguished centers of learning, one public and one private, joining together to accomplish what neither could have effectively accomplished alone." —ws

AIP Corporate Associates in St. Louis

McDonnell Douglas Corporation in St. Louis, Missouri was the host for the 1984 Corporate Associates meeting of the American Institute of Physics. The two-day meeting, held 23–24 October, was attended by 190 leaders of industry, heads of graduate physics departments, government officials, and officers of AIP member societies.

McDonnell Douglas has 90 000 employees in 38 states of the United States. The meeting participants were given a tour of the corporate research facilities, including labs for solid-state nuclear magnetic resonance and electron spin resonance spectrometry, mass spectrometry, and metal physics. They were shown experiments in internal, shear and jet flow; jet impingement and jet noise; and facilities for flight simulation, molecular-beam epitaxy and microelectronics fabrication. Immediately following the meeting, many participants toured a final assembly line and saw the Air Force F-15 Eagle, Navy F-18 Hornet and the marine AV-8B airplanes being fabricated.

The physics of high-performance materials was the meeting theme: Raymond Orbach (UCLA) discussed fractals and dilation invariance, explaining their application to amorphous materials and percolation networks. He applied fractal concepts to excitations in glasses and amorphous semiconductors. Bhakata Rath (Naval Research Laboratory) discussed rapid solidification processing, its scientific bases and technological advantages. For example, rapid quenching of metals and alloys can be used to make refined and novel microstructures by varying cooling rates and the alloy composition. Maurice Gell (Pratt & Whitney Group, United Technologies) discussed the development of single-crystal superalloys. For the last two years single-crystal turbine blades have been in commercial service and have flown over 750 000 hours. These giant crystals are formed by dendritic growth during directional solidification. A single crystal is obtained by use of a helical grain selector. Sanford Sternstein (Rensselaer Polytechnic Institute) discussed matrix-dominated mechanical properties of composites. One can adjust the failure mode, he said, by tailoring the properties of the matrix material.

On matters of policy, Hatten Yoder (Carnegie Institution of Washington) discussed strategic and critical minerals. He is concerned that the US access to these minerals is lessening with time. He mentioned many factors underlying potential world shortages, such as geochemical limits, increased energy consumption in extraction of lower-grade ore, and especially the extensive lead time in discovery and development. Alvin Trivelpiece (DOE Office of Energy Research) discussed fusion policy in the wake of Congressional cuts in the FY 1985 budget. (See PHYSICS TODAY, November 1984, page 57.) He cited some of the technological fallout from the fusion program. For example, he said, particle currents of neutral atoms for directed-energy weapons in the kiloamp range grew out of the "Alice" neutral-beam heating experiment at Livermore. The National Magnetic Fusion Energy Network, established a decade ago, has turned into a model for other computer networks.

William Brinkman (Sandia), who heads the National Academy of Sciences Physics Survey Committee, said that the subpanel reports are complete and that the overview report will stress progress in the last ten years and future opportunities. "We have not emphasized priorities in the sense of one subfield over another. You've got to support them all. We will give a general set of recommendations regarding the needs of physics as a whole."

Kenneth Wilson (Cornell) discussed cooperation with industry on supercomputing. Because today's computer market is $4 billion/year for VAX-level computers and graphics and only $100 million/year for supercomputers, the discrepancy in money makes computer companies declare, "We don't need high-performance computers." Wilson argues that you have to have the supercomputer to figure out what you can do with it. "We all need infinitely upgradable hardware," he believes, which can be obtained with mass-produced chips running in parallel to yield lots of performance at low price.

Alan Heeger (University of California, Santa Barbara) discussed semiconducting and metallic polymers, ranging from solitons to storage batteries. Polymer batteries, he said, have high current and power density, and are rechargeable; however, the systems are not yet sufficiently stable. Conducting polymers might also be applicable to electrochromic displays, transparent conductors and synthetic metals.

Boyce McDaniel (Cornell) discussed the Superconducting Super Collider. He expects that by October 1985 the magnet style will be selected and that by April 1986 the final conceptual design will be finished. Only a few