Thomas Banks (University of California, Santa Cruz), Nathan Seiberg (Institute for Advanced Study) and Steven Shenker (University of Chicago). Popularly known as "the string quartet," they were offered a package deal when university recruiters who were seeking one or another of them realized that they could get all the people they wanted by making a concurrent offer to all four. (While the term string quartet originally referred to a noted article by Gross, Harvey, Martinec and Rohm, it seems destined now to stick to the Rutgers team.)

Commenting on the quartet, Edward Witten of the Institute for Advanced Study says, "It is clear that Rutgers has hired some of the most original and independent-minded theorists in superstrings and conformal field theory." All four have had a big influence in recent years, Witten said. For example, Friedan and Shenker, working with Emile Martinec of the University of Chicago, solved the longstanding problem of the fermion vertex operator; Banks, working with Michael Peskin of SLAC, made an important contribution to string field theory; and Seiberg, with Gregory Moore of the Institute for Advanced Study, "enriched our understanding of so-called rational conformal field theory."

To some people, the decision to hire the quartet smacks of faddishness and politics. "It has all the elements of the bureaucratic process," remarks a physicist-turned-mathematician at New York University's Courant Institute. "Physics always has to have something flashy to sell, and a superstring is something you can sell to somebody like Reagan."

Responding to that kind of complaint, Browder says that he discussed the issue with Sheldon Glashow, a well-known critic of superstring theory, and that Glashow "answered his own question." Glashow told Browder he thought it was strange that half the world's theoretical physicists—*and the better half at that*—were doing string theory.

Besides, observes Leath, the quartet is to become the nucleus of a general theory center, not a center dedicated solely to string theory, and even if superstrings do turn out to be a flash in the pan, these are all first-rate people who one way or another will find very interesting problems to work on.

Allen Robbins, the chairman of the physics department, points out that the department already was strong in other aspects of theory and that recent appointments are making it stronger still. Condensed matter theorist Elihu Abrahams was elected last year to the National Academy of Sciences. The department has lured condensed matter theorists B. G. Kotliar and André Ruckenstein from MIT and the University of California, San Diego, respectively. Astrophysicists David Merritt and Carlton Pryor are coming from Canada's Institute for Theoretical Astrophysics and from Vanderbilt University.

Experimental work in the department is concentrated largely in solid-state physics, especially superconductivity and superfluidity, and in elementary-particle physics.

Discrete mathematics

Browder says people sometimes ask him how you spell "discrete" when conversation turns to the Center for Discrete Mathematics and Theoretical Computer Science.

The center is one of 11 selected last year by NSF from 323 proposals. It is jointly sponsored by Rutgers, Princeton University, AT&T Bell Labs and Bellcore. About 75 mathematicians and computer scientists from the four institutions are expected to participate in its work, and it is supposed to receive nearly $10 million in NSF funding over the next five years. The focus during the first year will be on discrete and computational geometry, a key element in robotics and computer design according to Gorenstein, the center's director.

A Center for Mathematics, Science and Computer Education, which was founded in 1984 at the behest of an organizing committee headed by Joseph Rosenstein, jointly sponsors education programs with the Center for Discrete Mathematics as an integral part of the NSF-supported mission. The education center has a number of ongoing projects, including a "discrete math project," in which area teachers are familiarized with algorithms and graphs, and a precalculus project aimed at the junior and senior years of high school, both run by Rosenstein; an elementary school math project; and the Secondary Science Modules Project, run by George Pallrand of the Graduate School of Education and Sidney Millman, a former physics research director for AT&T. (Pallrand and his colleague Peter Lindenfeld described the modules project in the October 1986 issue of PHYSICS TODAY). Lindenfeld, the most recent recipient of the American Association of Physics Teachers Robert E. Millikan Award, is chairman of the executive committee of the math and science education center.

The general philosophy of the math and science education center, says its director, Goldin, is that "excellent education must be based on close collaboration between scientists, mathematicians and teachers, meaningful partnerships between precollege education, university and industry, and an emphasis on the learning process as well as end results."

Surface science

Even before the arrival of Madey from the Bureau of Standards, the Rutgers Laboratory for Surface Modification was doing well, having recruited both Torgny Gustafsson and Robert Bartynski from the University of Pennsylvania. The capture of Gustafsson was featured, in fact, in a *Time* magazine article about corporate raiding!

The surface lab is a participant in a Sematech-sponsored consortium on surface science, in which the David Sarnoff Research Center also is an important player. But that is another story. . . . —WILLIAM SWEET

SARNOFF CENTER GIRDS LOINS FOR GLOBAL COMPETITION IN HDTV

Several years ago, when General Electric gave the RCA David Sarnoff Research Laboratory to SRI International, rumor had it in the greater central Jersey area that Sarnoff staff no longer had anything meaningful to do and that the lab was just collecting patent income from past inventions. That was not the case. Under the terms of the divestiture, GE was continuing to collect the patent income and Sarnoff staff, faced with the prospect of having to become self-supporting, were busily looking for new things to invent.

There was something about giving the lab away that left the impression that Sarnoff was worthless, or at least worthless to GE, and that SRI was doing everybody a big favor by taking over the lab. But those impressions also were off target. In fact, the transfer left the lab in sound financial condition for the short term, good prospects for the longer term, and with a continuing strong link to GE and, more generally, the consumer electronics industry.

The corporate ground

The story began three years ago when the two chairmen of GE and RCA agreed, with a handshake, to merge their two companies. The merger left GE with two research laboratories, and so its executives began to look for a way to consolidate operations at Schenectady. For advice, they brought in SRI International, the Silicon Valley company that originated as the Stanford Research Institute. As it happened, SRI President William F. Miller was looking to establish an East Coast facility, and even though Miller was known as a Silicon Valley founding father, SRI was not doing much in solid-state physics. The main body of SRI's work was in the behavioral sciences, biology and pharmaceuticals, computers and mathematics, and business consulting.

The more Miller and his associates looked at the RCA Sarnoff Center, the more interested they grew in taking over the lab themselves. Acquiring Sarnoff would give SRI a beachhead in applied physics and at the same time provide it with a base right square in the middle of what one Sarnoff executive calls "the biomedical Silicon Valley of the East Coast"—that is, the strip along Route 1 where companies like Johnson & Johnson and Squibb are located.

In February 1987 it was announced that GE would make a gift of Sarnoff to SRI. As part of the deal Sarnoff concluded a $250 million contract with GE to do research in consumer electronics for GE over a five-year period. The payment schedule was graduated downward so that independent contract work would gradually constitute a growing share of the lab's income as income from GE declined. The center proceeded to cut its staff by about a third. Of some 1200 employees, about 300 took advantage of early retirement schemes, and another 100 were let go on a merit basis.

In December 1987, tremors reached Sarnoff from a second corporate earthquake—the decision by GE and France's Thomson to trade Thomson's European assets in medical equipment for GE's North American consumer electronics business. Overnight, Thomson was the largest domestic manufacturer of televisions in the United States and probably the largest manufacturer of color televisions worldwide, and Sarnoff was working under contract for Thomson. Thomson now held about half of GE's five-year contract to Sarnoff, which it promised to supplement with another $30 million during the lifetime of the contract, plus another $30 million or so during the two years following the contract's expiration.

Internal reorganization

Of the 600 technical people currently at Sarnoff, about 40% have PhDs and perhaps 100 or 120 have degrees in physics. In the estimation of James J. Tietjen, president of the center, perhaps twice that number have degrees in electrical engineering. Tietjen himself holds a PhD in fuel sciences from Penn State and he started out working in materials research. He developed a method of crystal growth that's still used to produce light-emitting diodes.

Tietjen says that before SRI took over, government contracts—mostly defense— accounted for about 13% of the center's business. He says defense now is a growing part of the business and that the center is shooting for a ratio of about 50% military–50% civilian work. He notes that the engineering group at SRI is very strong in computers and mathematics and that it does a lot of government work, much of it classified. Another potentially useful asset is SRI's international business group, which has offices in about 15 countries.

Turning to Sarnoff itself, Tietjen sees the center's understanding of human vision, and its ability to bring that knowledge to bear on machine vision, as one of its strengths. He says the center is developing a processing system based on human vision, and that the center has the potential to be the leader in the field. Applications would be in robotics, military surveillance and security systems.

Tietjen sees photography companies as another potential market for Sarnoff. Among the relevant work is digital-video interaction technology developed at the lab, "a very powerful compression technique that permits completely random interaction." The system was developed in the center's consumer electronics and information sciences division, which is headed up by James E. Carnes. GE withheld the center's DVI group of 35–40 researchers from the deal with SRI and recently sold the group to Intel, which soon will move it to new quarters in the Princeton area. This was a one-time arrangement, not a precedent, and Sarnoff got a small percentage of the GE take.

Other outstanding research areas mentioned by Tietjen include optoelectronics (injection and surface-emitting lasers), solid-state physics (silicon on sapphire insulators), and information systems (artificial intelligence and neural networks).

In superconductivity, Tietjen says the center is looking hard for practical applications, for example, uses in microwave devices.

Historically, Sarnoff claims many basic inventions in general electronics, among them the metal oxide semiconductor, the CMOS, liquid-crystal technology and amorphous silicon. One of its more recent inventions is a surface-emitting diode laser, which has possible applications in ultrahigh-speed optical computing. The device relies on a grating to redirect and sharpen beams. It was developed by the solid-state research division, which is headed by Carmen A. Catanese, vice president for solid-state research. (Catanese is a physicist who earned his PhD at Yale in 1970.)

Until the end of last year the solid state division supported GE (previously RCA) Solid State, a manufacturing unit in Somerville, New Jersey. That unit was sold to the Harris Corporation in Melbourne, Florida, at the end of last year. But Catanese expresses optimism about his division's ability to survive in a more competitive market. He says that before the takeover, RCA was "pulling back" from many areas and was unwilling to be "adventuresome," and so "what is going on now is much more exciting."

Catanese says his people are "quite good at talking with clients about inventions that will have a big impact down the road. Show us problems that aren't walk-through kinds of problems, and we'll tackle them."

The center's most frustrating recent experience involved the technical success and market failure of the optical videodisc, which was developed in the manufacturing and materials research division, headed by Jay J. Brandinger, when Sarnoff still was with RCA. RCA and the center underestimated the importance that the ability to do home recording would have in the market and lost out to magnetic-tape systems providing that capability. But the center's confidence in Brandinger seems undiminished. One of his groups is an important participant (with Princeton, Rutgers and the Stevens Institute of Technology) in a Sematech consortium in advanced plasma etching. Another is working with Superconductor Applications Inc, a newly founded New Jersey consortium.

High-definition television

Sarnoff's most famous invention, of course, is the color television system that was adopted as the US national standard in the early 1950s. It was the product of many years of research

on tube development by the group around Vladimir K. Zworykin, perhaps the most glamorous figure in the center's history.

Now the center's sights are set on high-definition television, which is quite important in its business planning, Tietjen says, and which also could be quite important to the performance of US electronics companies in the 1990s.

Work on the Sarnoff Center's HDTV system, which it calls Advanced Compatible Television (meaning it is compatible with current television sets), is centered primarily in Carnes's shop, but Brandiger's division also does important R&D on things like materials development for screens. The research accounts for 35–40% of staff time in Carnes's division and a not insubstantial fraction in Brandiger's.

On 19 April, the 50th anniversary of the first public broadcast of television at the New York World's Fair in 1939, the lab successfully transmitted what it refers to as "first phase" ACTV images from the top of the World Trade Center in Manhattan to receivers at Sarnoff in Princeton. Carnes said on the occasion: "This is the first time that anyone has successfully broadcast advanced television signals by regular terrestrial means. This clearly puts us in a leadership position." Zenith, which is working on advanced television R&D in conjunction with AT&T, issued a statement warning that it would be a serious mistake for the Federal Communications Commission to adopt a standard based solely on evaluation of a first-phase system. (Zenith often is referred to as the only surviving American television manufacturer, but what this means is that it is the only American-owned manufacturer; Thomson and Phillips both are larger manufacturers of televisions in the United States.)

James H. Clingham, Sarnoff's vice president for legal and public affairs, says that half the work under the $250 million GE contract still is directed by GE divisions but that the part pertaining to television is directed by Thomson through its consumer electronics group in Indianapolis, Indiana. The GE–RCA television people who were transferred to Thomson are still running the show, to be sure, but the center also is beginning to cooperate with several labs in Europe that Thomson has working on HDTV. Carnes says the center is continuing to work rather independently on a transmission system suitable for use in the United States, but that there is increasing cooperation with the Thomson staff on other aspects of HDTV design.

Because of big questions concerning consumer preferences in the 1990s and alternative methods of image transmission such as fiberoptic cable, HDTV is a big gamble, and everybody knows it. But to the extent it continues to be a focal point of global competition in the next ten years, Sarnoff seems certain to stay in the center of things. —WILLIAM SWEET

INSTITUTE FOR ADVANCED STUDY: PAST AND FUTURE

Marvin L. Goldberger took over as head of the Institute for Advanced Study in September 1987, returning after nine years as president of Caltech to the town where he lived and worked as a physicist from 1957 to 1978. On 26 April, Goldberger stopped in at PHYSICS TODAY*'s office in Manhattan to discuss the state of the institute.*
—WILLIAM SWEET

PT: Ed Regis goes on in his book *Who Got Einstein's Office?* [Addison-Wesley, 1987] about how isolated the institute is from Princeton and the university. What is the feeling about those relationships now?

Goldberger: It has gone through phases. When Robert Oppenheimer came, it was a place that was a little mysterious, inhabited by people who talked with funny accents. They were not people who had been undergraduates at Princeton and they were not rich. Einstein, of course, shed a tremendous aura over the institution and over the town, but there was really very little interchange between the people of the institute and the people of the town. For whatever reason, Oppenheimer was not clasped to the bosom of the town. He tended to be, I think, a little arrogant and the Princetonians didn't appreciate that. As for relations between the institute and university, from an intellectual standpoint, I think that those probably have always been very close. The institute was originally housed in Fine Hall, the mathematics building of Princeton University, until the opening of the present campus, which didn't come until 1939.

I suspect there are still people in Princeton who don't really know very much about the institute: They don't know exactly where it is and do not clearly understand that it is a free-standing institution that has no formal connection with the university. We are entirely separate financially and administratively, though there is very strong interaction at an intellectual level. There are joint seminars in all the areas we are involved with, and we are in and out of each other's pockets, not financially, but intellectually.

I've been particularly anxious to work toward strengthening the relationships between the institutions with an eye to seeing how we could help each other—how we could complement each other to make the whole greater than the sum of the parts. There are a few formal things that we are trying to initiate, but by and large, strengthening the informal relations is the most effective. People of the institute faculty teach on a voluntary basis. They take graduate students and supervise theses. So there is already a lot of progress.

PT: The institute still doesn't grant degrees?

Goldberger: We don't grant degrees, although technically we are a degree-granting institution. It was Abraham Flexner's original idea to have graduate students, but he was talked out of that by Veblen, who said instead it should be a postgraduate institution. [Flexner was the institute's first director, and Oswald Veblen was the first head of the institute's school of mathematics.]

PT: What about your relations with other institutions?

Goldberger: For example, there has been at the institute for the past 17 or 18 years a weekly astronomy lunch, which is attended by people up and down the Eastern Seaboard interested in astrophysics. Tony Tyson comes down from Bell Labs. People occasionally come from the Exxon research labs. They come from Rutgers, Columbia, the universities of Maryland and Pennsylvania, and of course Princeton University. They come for lunch [specifically] because we have the best dining room in a radius of 100 miles, or at least 50 miles. There is an analogous social science lunch, usually with 50 or more people from the institute, including some physicists, and from Princeton, Rutgers and so on.

People from all four schools of the institute—mathematics, physics, social sciences and historical studies—very frequently attend seminars and participate in programs with colleagues from all neighboring univer-