A Special Relationship

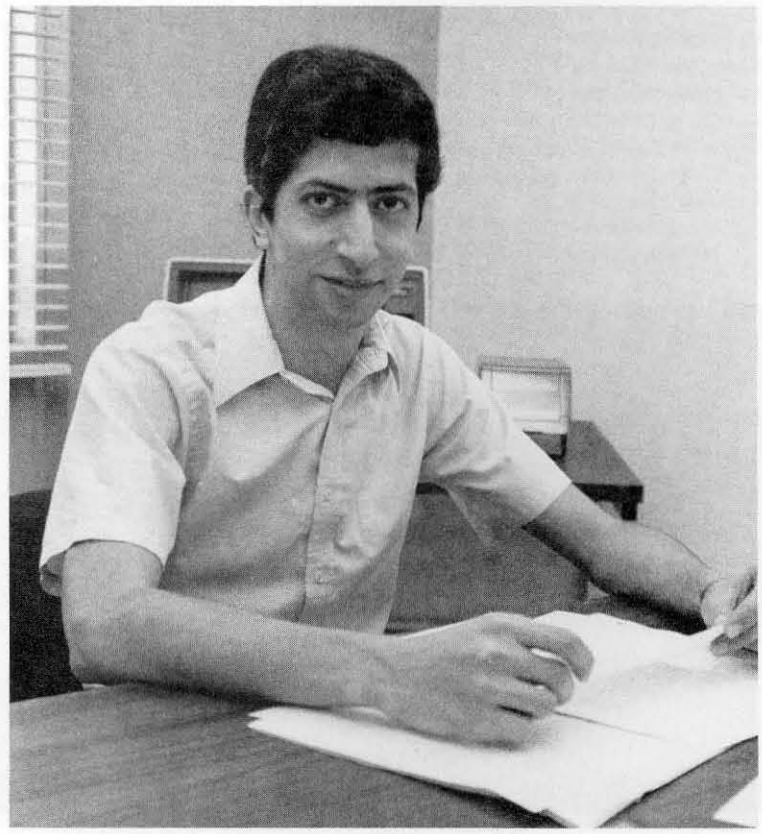
YASER ABU-MOSTAFA, assistant professor of electrical engineering and computer science, does theoretical work on pattern recognition — how a computer might go about recognizing a visual object, a task quite natural and simple for the human brain but a formidable job for a machine. In fact, a computer fails miserably at recognizing something as obvious to us as a tree, for example, because computers are systematic and structural. Recognizing the visual image of a tree is a vague and unstructured problem, a type of problem called in mathematics random in the Kolmogorov sense.

Abu-Mostafa is trying to develop a theory of computation for such random problems, to figure out how a computer might actually undertake solving them. His previous work (he earned his PhD from Caltech in 1983) has also been mathematical and theoretical — describing the general complexity of such natural problems and estimating what the "cost" would be, in terms of computer time or memory, to solve them. But he also wants to be able to apply his theoretical framework of pattern recognition and, working with his Caltech colleagues, design digital systems that can actually recognize images.

Although he is a theorist motivated by the intriguing questions involved, Abu-Mostafa is pleased that his research does have applications — from military radar to computerized vision for the blind. His work is typical of the sort of basic research that underlies future technological progress and that establishes the primary motivation for universities and industry to work together in planning for the future. And in fact, Abu-Mostafa's work in pattern recognition is one of seven projects being supported by the Program in Advanced Technologies, a joint undertaking by Caltech and four industrial sponsors announced in the fall.

The structure of the Program in Advanced Technologies, more familiarly known as PAT, was carefully hammered out over the last three years by Caltech and the companies involved and may serve as a model for future industry/academia arrangements. It is viewed

Yaser Abu-Mostafa



by the participants not as an outright grant but as, according to Ruben Mettler, chairman of the board and chief executive officer of TRW Inc., "a special relationship for addressing a number of advanced technologies that will be critical to society in the 80s and 90s." Mettler is also Caltech's new chairman of the Board of Trustees (as of January 1).

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Caltech President Marvin Goldberger, former Provost John D. Roberts, former Vice President for Institute Relations Dwain Fullerton, and former division chairman Roy Gould participated in the initial conception of the program. The Institute's current Provost, Rochus Vogt, has been instrumental in the program's implementation.

The four companies will each contribute $200,000 annually for five years to support research in fluid dynamics, electronics, and solid state materials. Half of that will go directly to research, the other half to Institute and division discretionary funds, which will include equipment grants and graduate fellowships. Control of the program remains within the traditional academic structure, but the process of deciding which research to support depends on the input of a committee of Caltech faculty and industry representatives. In fact, the collegiality of the program is one of its unique aspects. "It offers a tremendous opportunity to share ideas and concepts and to critique ideas of the future in technology, which we often see from different perspectives," says Arden Bement, vice president for technical resources of TRW.

TRW was the first company to conceive, with Caltech, the idea of a consortium of companies playing a positive role in supporting a broad spectrum of research at the Institute. GTE Laboratories and Aerojet General subsequently enlisted in the program, and General Motors joined up this month. One of the strengths of the program, as William Nelson, director of collaborative research for GTE Laboratories, sees it, is the relatively small number of sponsors. "So there's a degree of compatibility and some technical overlap, but at the same time we're not competitors fundamentally. And all the sponsors are sophisticated in their own right; we carry on sizable research efforts of our own," says Nelson. Although the main benefit to the sponsors is working with Caltech faculty, there are also potential tangential benefits from working with other companies, he believes.

Another of PAT's strengths is the flexibility provided by its scope. This came about in the very early stages of negotiation, when a team of TRW's technical people visited the campus to explore what sort of research might be meaningful to them. After meeting with about 20 faculty members, the visitors decided they liked everything they had seen. Except for making the program difficult to name, this diversity has proved to be a definite plus for all the participants. "It's not dependent on a single individual or a single technical link," says Nelson of GTE, "and yet it's not so broad that there's no focus either."

The interdisciplinary nature of Caltech's research groups is particularly well suited to this sort of program. "Many of the advances that could enhance the progress of a wide range of industries over the next decades require bridging the gaps between traditional disciplines, which Caltech faculty are eminently able to do," says Goldberger.

Research proposals are solicited from faculty in the three broad areas — fluid dynamics, solid state materials, and electronics — covering, from the sponsors' point of view, something for everyone. Under fluid dynamics, the topics of interest are reacting fluids (chemical lasers, combustion, metastable two-phase flows, mixing, turbulence, and vortex control) and computational fluid mechanics (boundary and shear layers, downstream conditions, and new computational techniques).

The area of solid state materials includes metals (amorphous materials, dynamic compaction, sputtering, ion implantation, and failure of materials) and semiconductors (surfaces, interfaces, lattices, ion implantation, epitaxial growth, device applications). Under electronics three areas are under consideration: power electronics (models, analysis methodology, devices); electronic systems (error-correction coding, control and robotics, digital signal processing, image processing,

electro-optic systems); and electronic devices and technology (integrated opto-electronics, millimeter and submillimeter wave devices and components).

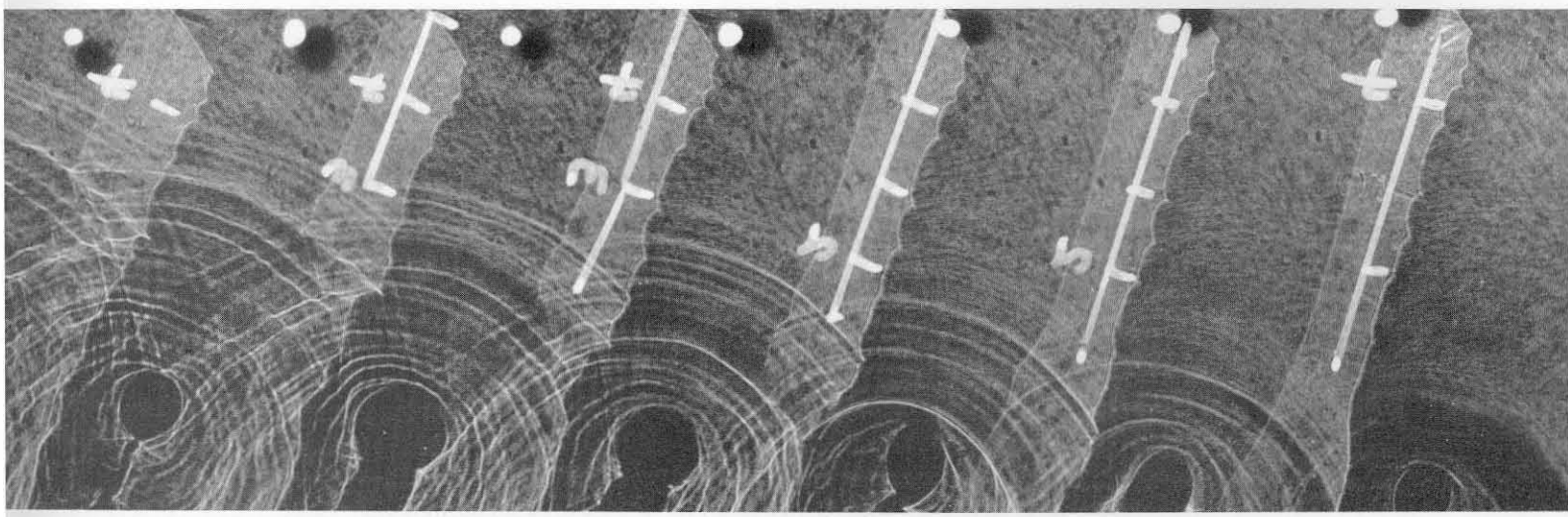
One of PAT's principal objectives is support of new research efforts undertaken particularly by new or junior faculty — "for promising young faculty members with bright ideas, who might not otherwise get a chance to try them out," according to Vogt. But proposals from senior faculty are also considered, especially in those areas where there are currently no junior faculty. Proposals for research projects are submitted to PAT's advisory committee, which will evaluate them, rank them, and make recommendations. In a way, it will act as a mini granting agency. The first chairman of that committee, as well as the designated principal investigator who will administer the program, is William Bridges, the Carl F Braun Professor of Engineering. Bridges, who spent 17 years in industry at the Hughes Research Laboratories before joining Caltech in 1977, says, "I agreed to serve as manager for this program because of my strong belief that the interests of both the Caltech faculty and their industrial counterparts will be greatly enhanced by the technical dialog that PAT will create."

The advisory committee consists of a representative from each industrial sponsor and an equal number of Caltech faculty members, appointed by the chairman of the Division of Engineering and Applied Sciences. Paul Jennings, professor of civil engineering and applied mechanics, has recently assumed this post. The division chairman will also determine the final distribution of funds. Overall responsibility for the program lies with Vogt.

Current members of the committee are Nelson of GTE; George Gleghorn, vice president and chief engineer, Space and Technology Group, TRW; James Myers, vice president, operations, Aerojet General Corporation; and John Caplan, executive director, Research Laboratories, General Motors Technical Center. Caltech's representatives, besides Bridges, include Frank Marble, the Richard L. and Dorothy M. Hayman Professor of Mechanical Engineering and professor of jet propulsion; Robert McEliece, professor of electrical engineering; and Thomas McGill, the Fletcher Jones Professor of Applied Physics. In addition, Terry Cole, Chief Technologist at the Jet Propulsion Laboratory, is the insider/outsider on the committee; he's also senior research associate in chemistry and chemical engineering at Caltech.

This collegiality of decisionmaking is an aspect of the program that all parties find particularly satisfactory. Robert Carroll, director of engineering and research at Aerojet Tactical Systems Company, one of Aerojet's five divisions, finds that "it gives Caltech almost the benefit of an outright gift, but it's a lot better than an outright gift for us." Carroll, who serves on an Aerojet internal steering committee that also got a chance to rank the proposals, says that "even if we're not in direct control, we can help select what direction the research goes in." The top five proposals ranked by the Aerojet committee ended up getting funded.

PAT's first awards were announced at the end of November. Grants totaling $300,000 went to seven faculty members. Associate Professor of Electrical Engineering Slobodan



These high-speed photographs show dynamic caustic patterns formed around the tip of a fast-moving crack. The time between frames is five microseconds. A PAT equipment grant provided an argon ion laser for the high-speed camera system.

Cuk will be working on power electronics inverter topologies, and David Rutledge's proposal is to design a square array of field-effect transistors as amplifiers in a millimeter-wave power generation system. Rutledge is also an associate professor of electrical engineering. P.P. Vaidyanathan, assistant professor of electrical engineering, received a grant to develop efficient design methods for digital filters requiring few or no multiplications and to apply these filters in digital communications, including speech transmission.

Fred Culick, professor of applied physics and jet propulsion, will develop programs on an advanced, interactive computer graphics system with animation to analyze the unsteady internal flows in combustion chambers. And two grants were in the field of materials science. Professor Thad Vreeland is investigating production of metal glasses in bulk samples larger than currently possible by consolidating amorphous and crystalline powders with strong shock waves followed by solid state reactions. Professor William Johnson is interested in preparing a variety of thin films and coatings of refractory metal glasses and studying their properties of unusual hardness, high strength, adhesion, and stability at high temperatures.

Jennings and Bridges also announced three equipment grants totaling $75,000. One of these is a high-rate sputtering system for William Johnson's work preparing thin films and coatings of metal glasses under controlled conditions. Ares Rosakis, assistant professor of aeronautics and applied mechanics, received a grant for an argon laser for a high-speed camera system. The camera, capable of half a million frames per second, will be part of an experimental setup for the study of the dynamic fracture of structural metals. The optical patterns (caustics) recorded by the camera allow measurement of the stresses at the tip of cracks propagating with velocities of the order of a kilometer per second. Bradford Sturtevant, professor of aeronautics, will use his grant for digital transient recorders, a data acquisition system to be used in a number of experiments simulating vapor explosions such as might occur in nuclear reactors and volcanoes.

Three graduate fellowships were also announced: Michael Atzmon, in applied physics, is the Aerojet Advanced Technologies Fellow; Ed Schlesinger, also in applied physics, is the GTE Advanced Technologies Fellow; and Alan Zehnder, in mechanical engineering, is the TRW Advanced Technologies Fellow.

PAT guidelines, which were developed in concert, also follow academic tradition with regard to "intellectual property" and publication rights, which have historically been sticky points in negotiating industry/university collaboration. Under PAT, there are no restrictions on publication, although researchers are asked to send papers to the industrial sponsors at the same time that they submit them for publication. All intellectual property will belong to Caltech, which will grant nonexclusive licenses to the participating companies.

This is largely due to an "open stance" on these issues on the industrial side, according to TRW's Bement. "We don't see it as a quid pro quo, but rather a long-term relationship that we agree to help nurture along. We didn't want to pose a threat to the normal prerogatives of university members." But, he adds, "we also had interests that Caltech honored; we had respect for each other's positions."

The participating companies seem to agree that the major benefit is the collegiality of the program, the interaction with people. A key feature of the program is that Caltech will host two meetings a year for presentations and discussion of research by faculty and industrial participants. The first of these meetings will take place this spring. According to Bridges, "These meetings will serve as a forum for the Caltech people to report their program and for industrial researchers to present their problems and results to us; we want it to be a two-way street. I've seen research activities from both viewpoints in my career, and I feel strongly that both academic and industrial researchers can benefit greatly from hearing each other's tales." By mutual agreement companies may also send their scientists to work with Caltech faculty.

For Bement, when you get the technological know-how of industry together with the deep scientific insights of academia in a relationship of this quality, new concepts and new pathways for applications are bound to emerge. "It's a sharing of vision of where technology is going," he says. "Anticipating where the real opportunities are going to be a few years in advance is a tremendous advantage to any company. It contributes to our ability to manage technological change in a fast-changing world." □ — *JD*